SURGICAL TREATMENT

BANCROFT
AND MURRAY

MOTOR SKELETAL SYSTEM

PART ONE

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MOTOR-SKELETAL SYSTEM

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PART ONE

Deformities, Paralytic Disorders, Muscles, Tendons, Bursae, New Growths, Bones, Joints, Amputations

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Supervising Editor's Note

Some time ago when this work was still definitely in the prenatal stage, the editor made a careful and exhaustive survey of all the available books dealing with the broad subject of surgical treatment. This survey showed clearly that, while there was no lack of books, there was none filling a certain need. The foregoing statement should not be taken as implying that the existing works on surgery are without merit. Many of the works on operative surgery list a large number of operations, although many of these operations are now obsolete or at least obsolescent, and are of historical rather than of current clinical interest. Also, in many instances, the reader is not fully informed concerning the difficulties, disadvantages, and contraindications for the various procedures, the discussion being limited to the operation itself.

The editor determined, therefore, that the present was an opportune time to produce an entirely new work on surgical treatment. It seemed advisable to establish a pattern of treatment and coverage for each field which would safeguard against omissions and would present the up to date, authoritative material in the most concise and usable form. This pattern would include not only the operation itself but also indications for it, a full discussion of the preoperative preparation of the patient, the common sequelae, a full presentation of the prognosis, and a complete discussion of the most approved postoperative treatment. In this connection it was recognized by the editor, the associate editor, and the individual contributing authors, that because of the special problems in presenting some fields, this pattern should not be a straitjacket but that some concessions and commonsense adjustments would have to be made.

Since this is primarily a work on surgical treatment, no attempt has been made in general to present the diagnostic problems or the etiology. However, these subjects have been taken up when it seemed necessary in order to assure attainment of the over all picture which it is the purpose of the book to present.

The bibliographic references have been carefully selected to cover only the most important material rather than to accumulate a long list which, while they may bear testimony to the erudition and diligence of the author, would be of little value to the reader.

FREDERIC W. BANCROFT

Preface

Disregarding the outmoded and illogical attempts which are still made to define strictly the mutual limits of orthopedic surgery and general surgery, these volumes purpose to present the surgical treatment of all conditions involving a physiologic unit—the motor skeletal system The system is comprised of the skeleton and those structures which provide for its support and motor activity—the bones the joints which articulate them, the muscles, tendons, fasciae and ligaments which motorize and stabilize the joints, and the bursae associated with those structures Neurologic structures as such do not belong in this system, but the results of neurologic lesions may require operation or other surgical treatment applied directly to the motor skeletal structures affected Only such results of neurologic lesions are dealt with On physiologic grounds there are therefore included all conditions which involve the skeleton and the structures directly concerned in its support and motorization, whether the disturbing lesion be trauma disease, tumor, or deformity On the same basis lesions of the extremities or trunk not directly involving the functioning of the motor skeletal system have been excluded

The title, Surgical Treatment, implies that all procedures, operative as well as nonoperative utilized in the care of the individual conditions are included in the text All discussion of the general features of operating room technic, pre and post operative care of the patient as a whole, chemotherapy, and similar phases of general surgical care are omitted Any variation from ordinary surgical technic called for in the surgery of the motor skeletal system will be specifically cited

These are not designed as reference volumes They are designed for the use of the average general surgeon and orthopedic surgeon over the country at large who has to deal with lesions involving the motor skeletal system The material has been presented from the standpoint of indicating what to do, when to do it, how to do it, and what not to do for the various conditions affecting this system The subject matter is grouped, insofar as is possible according to the type of disturbance involved and the individual contributors have been given great latitude in the expression of their personal opinions and preferences At the same time, the attempt has been made to include all of the more commonly used and justified procedures This naturally leads in some instances to seemingly contradictory opinions by the various contributors on treatment rationale or procedure in various regions of the body Where these apparent contradictions are not adequately discussed in the text, the reader will find explanatory editorial comment or will be referred to a section in the second volume (Chapter 22) on general considerations to clarify the situation This arrangement allows we believe, the inclusion of all valid viewpoints in the presentation of the subject

There is some duplication in the description of operative procedures This has been allowed to stand whenever an individual contributor s description contains a variation or variations in technic and procedure which are a matter of interest or practical importance Cross reference to such duplication is provided in the text by the editor, who has enclosed his interpolated remarks within brackets

The illustrations are designed to combine

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SECTION ONE

DEFORMITIES

1

Congenital Anomalies of Upper Extremity and Shoulder Girdle

FRANK R OBER, M D

The treatment of congenital malformations of the upper extremity may be divided into three groups as follows Those for which nothing can be done those which can be helped by conservative measures those which can be aided by surgery

The improvements in surgical technic over the past 25 years have cut down somewhat those conditions which were formerly considered to be beyond the range of surgical help Many of the second group are helped by the use of apparatus which concerns the surgeon The helpless cases will not be discussed here since surgical treatment only is to be considered

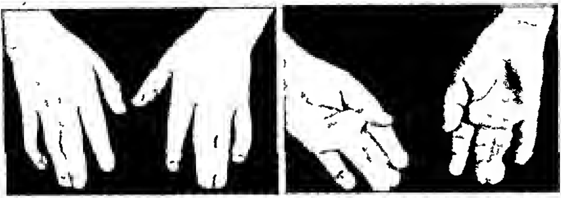
No part of the upper extremity and shoulder girdle is exempt from a congenital disability These disabilities vary from an extra finger to a complete absence of an extremity

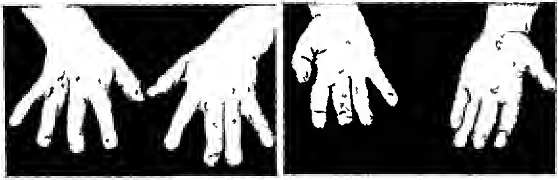
WEBBED FINGERS (Figs 1, 2, and 3)

MacCollum advocates optimum times for operation, depending upon the type of webbing as follows In those cases where the web is loose enough to allow some fanning of the fingers and does not interfere with growth, the time selected is at the sixth or seventh year, but when the fingers are tightly bound, or there is bony union, he sets the time at two years as the minimum and four to five years as the maximum

MacCollum Operation A triangular flap is made on the dorsum of the fingers a second and narrower flap is made on the palmar surface (Figs 4 and 5) The fingers are next separated after incision along the web to its tip (Fig 6) leaving two raw surfaces The triangular flaps are drawn between the fingers and sutured to each other (Fig 7) The raw surfaces are covered by thick razor grafts sutured in place with No 0000 catgut (Fig 7) Irrigation beneath the grafts is done to remove serum or blood and dressings with moderate pressure to prevent reaccumulation are immediately applied The hand and forearm are splinted on a Y splint, designed to keep the fingers separated and which is applied to the dorsal surface The second dressing is done on the eighth day and is then changed every two or three days At the end of 14 days gentle massage and exercises are started, and in three weeks a light splint is applied which keeps the fingers separated This is worn for six months during which time active exercise periods are continued

[Many men stress the fact that the bases of the triangular flaps should be as broad as conveniently possible and that the apices should be somewhat rounded rather than acutely pointed In separating the fingers it is, of course, essential that the dissection meticulously avoid injury to the digital vessels and nerves The inner side of the arm is a convenient and good place from which





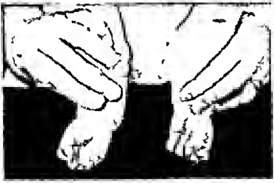


FIG 1 (*Top*) Web fingers, front and back Children's Hospital case
FIG 2 (*Center*) Result, one and a half years postoperative
FIG 3 (*Bottom*) Marked syndactylism Preoperative

to take grafts, and the use of the dermatome gives grafts of uniform thickness from which an exact pattern of the defect can be cut. Careful and exact fitting and suture of the graft is important.—Ed.]

SUPERNUMERARY DIGITS

The treatment of supernumerary fingers is removal of the extra digit after x-ray study If the extra digit has a corresponding metacarpal joint, the metacarpal bone is usually incomplete and the removal of this bone is advisable also, since to leave it will result in an unsightly wide gap between the

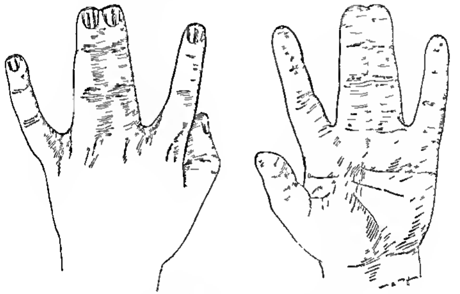


Fig. 4 Drawing of webbed fingers. (Courtesy, Surgery, Gynecology and Obstetrics, 71:782-789)

fingers. It may be necessary to do an osteotomy through the bases of the metacarpals lateral to the incomplete metacarpal, in order to obliterate the gap which results from the removal of the supernumerary bones. The hands should be kept bound for a period of four to six weeks, or until firm healing has taken place

There is no surgical treatment indicated for absence of one phalanx.

In absence of all the phalanges the possibility of stripping and isolating the terminal half of the first metacarpal should be considered three Splinting over a ball of sponge rubber placed in the palm of the hand and stretching exercises will accomplish a good deal in the first two or three years of life, especially in such contractures of the middle and terminal phalanges Contractures of the metacarpophalangeal joint are harder to overcome. In such instances capsulotomy of the posterior capsule may be necessary, to be followed by corrective flexion splinting, or osteotomy of the neck of the metacarpal and flexing of the distal fragment may compensate for the deformity.

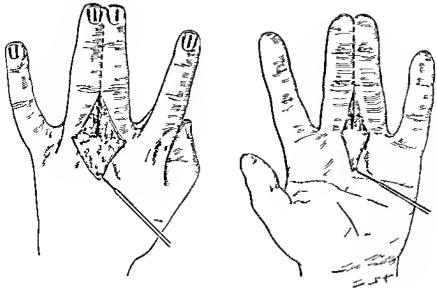


FIG 5 First step in operation of webbed fingers (Courtesy, Surgery Gynecology and Obstetrics, 71 782 789)

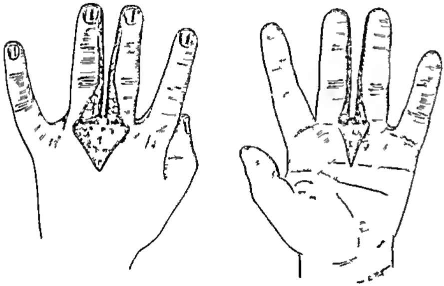


FIG 6 Second step in operation (Courtesy, Surgery, Gynecology and Obstetrics, 71 782 789)

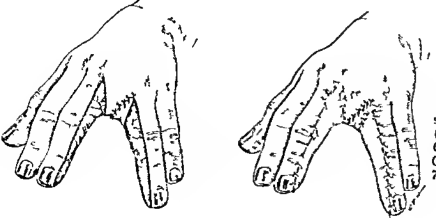
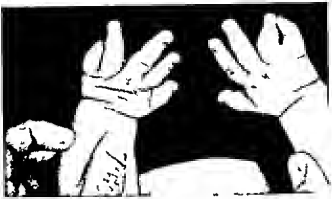


FIG 7 Final steps in operation (Courtesy, Surgery, Gynecology and Obstetrics, 71 782 789)



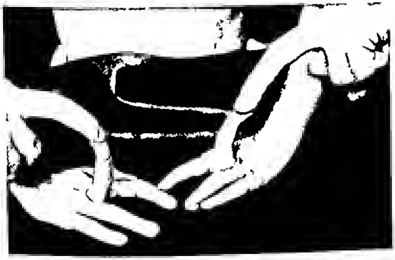


FIG 8 (*Top, left*) Congenital anomalies of fourth and fifth fingers
FIG 9 (*Center*) Flexion deformity, fifth fingers, bilateral
FIG 10 (*Top, right*) Congenital flexion anomalies of thumbs
FIG 11 (*Bottom*) Hypermobility of fingers

FLEXION CONTRACTURES OF FINGERS

These usually occur in the fifth digit (Figs 8 9, 10, and 11) The early treatment

ABSENCE OF METACARPALS

In total absence of the metacarpals it will be necessary to use a prosthesis (Figs 12, 13, 14, and 15) These are of two kinds

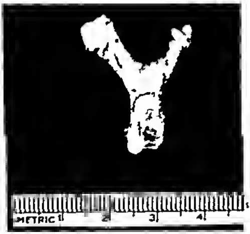


Fig 12 (*Top*) Absence of fingers with bifid third metacarpal
Fig 13 (*Bottom*) Bifid third metacarpal removed at operation

is frequent manipulations and the application of a palmar splint in corrective position In persistent cases it may be necessary to lengthen the contracted structures, principally tendon and capsule, surgically The after treatment consists of a palmar splint in the corrected position for three weeks followed by exercises

cosmetic and practical The cosmetic artificial limbs are useful within limits, and can be made more so by kineplastic operations as advocated by Vanghetti, Sauerbruch, and Kessler [See Kessler on Cineplastic Amputations, Chapter 21 —Ed] The cosmetic prosthesis may be constructed so that the hand can be removed by unscrewing,

and some convenient hook or other fixture applied An affair of this sort is of great use to workmen In a total absence of all the metacarpals the application of an artificial hand is necessary for cosmetic effect The artificial hand can be removed and many acts can be performed by the carpals if there is motion at the wrist stituted to improve function of the member

ABSENCE OF WRIST

In absence of the wrist (Fig 16) the treatment is an artificial hand In such cases a kineplastic stump may be constructed so that one may obtain motion in the thumb and forefinger of an artificial hand [See Kessler on Cineplastic Amputations, Chapter 21 —Ed]

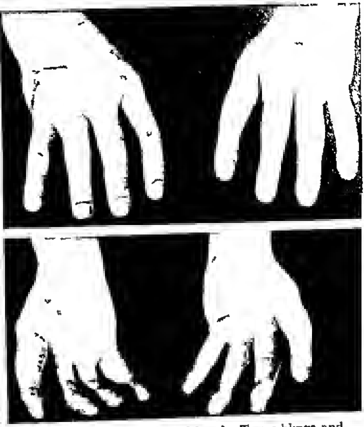


Fig 14 (*Left*) Rudimentary thumbs with radial deviation of hands Two siblings and father had similar deformities

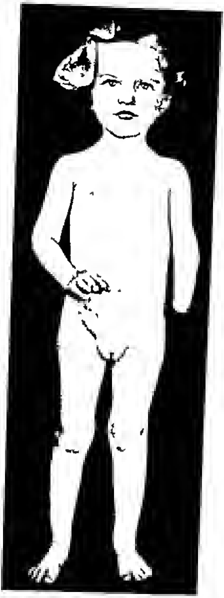
Fig 15 (*Right*) Father of boy shown in Fig 14 Absence of thumbs and radial deviation of hands (Front and back views)

Absence of the first metacarpal is often associated with absence of the radius and for this combination there is no treatment In the absence of the three middle metacarpals, osteotomy at the bases of the remainder will improve the function of the hand if the osteotomized bones are rotated and the tips are approximated This hand is not sightly, but is far more useful than an artificial member After the bones have healed, physical therapy measures may be in

CLUB HAND

Club hand is seen as a result of contractures of the radial or ulna extensors and flexors and the lateral or medial ligaments (Figs 17, 18, and 19) In infancy these usually respond to frequent manipulations by the nurse or mother In the more resistant cases it will be necessary to use retention

apparatus following the manipulation. Plaster encasements may be applied at weekly intervals, an effort being made to secure more correction each time the plaster is



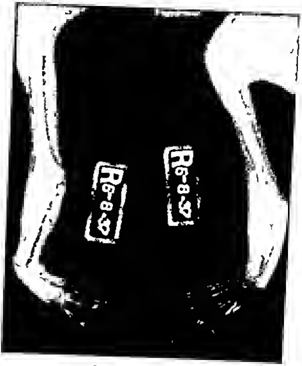


FIG 16. (*Left*) ·
FIG 17. (*Top, right*) Congen· ... and hand
FIG 18. (*Bottom, right*) X-ray ... with absence of ·

applied. Adjustable splints are also usef. in correcting these deformities.

In club hands due to absence or ·ing of a forearm bone, every-day manipulations must be carried out to minimize deformity until more definite procedures are indicated It is usually well to wait until the child is five or six years old before operating on the bones of the forearm. In

lengthening procedure is begun and continued over a period of four or five weeks The extension is left on for ten weeks and then removed The hand and forearm are put up in plaster from the fingertips to the axilla (elbow flexed) until the bones have solidly united

are corrected When this has been accomplished the old wound is opened and a large bone graft from the tibia is doweled into the end of the proximal ulna It is one quarter of an inch thick and extends through the cortex on both sides When this is done the end of the ulna fragment re

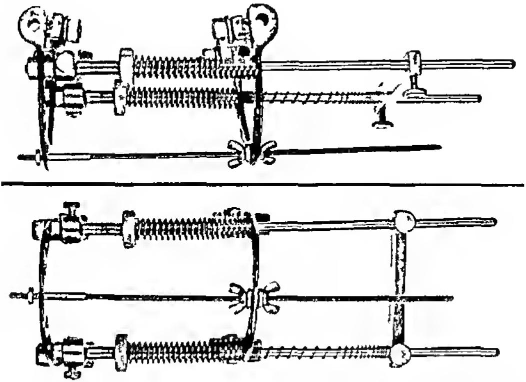


Fig 19 Illustration of traction apparatus to be used in lengthening short bones in forearm also used when grafts are placed for missing forearm bones [The yokes are fastened to wires or thin pins in proximal and distal portions of radius Nuts on side bars are adjustable to create desired tension on springs which push against one yoke while amount of stretching desired or advisable is regulated by central bar and set screws *Circulation of extremity must be carefully watched*]

When there is partial absence of the ulna there is usually a short stub of bone at the proximal end and a growing epiphysis at the lower end (Figs 20 and 21) These fragments are joined by a band of dense fibrous tissue The fibrous tissue is removed and a skeletal traction bone lengthening machine is applied (Fig 19) In ten days the lengthening is begun and continued gradually until the position of the hand and wrist

sembles an old fashioned clothespin into the prongs of which the graft is wedged (Fig 22) The graft must fit snugly and should be held in place with sutures The lower end of the graft must be in close contact with the lower ulna epiphysis The skeletal traction is left on in order to maintain absolute immobilization until firm union has taken place A plaster is next applied and worn for three or four months (Figs 23 and

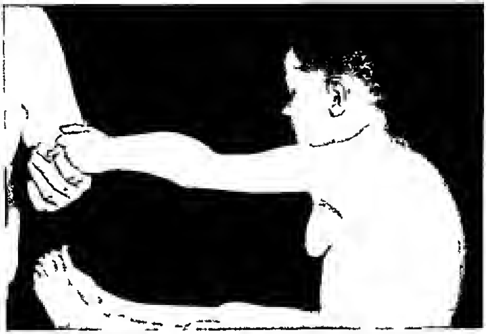


FIG 20 (*Top*) Club hand associated with partial absence of ulna
FIG 21 (*Bottom, left*) X ray of arms of patient shown in Fig 20
FIG 22 (*Bottom, right*) Postoperative result illustrating growth after application of massive bone graft

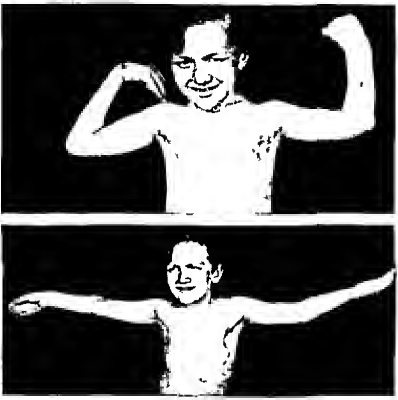


FIG 23 (*Left*) Postoperative result in patient shown in Fig 20—eight months
FIG 24 (*Right*) Postoperative result in patient shown in Fig 20 Note closure of hand patient was unable to close it before operation

24) Exercises are prescribed early in order to improve the function of the fingers After four months, exercises of the wrist and fore arm are added

The same procedure may be followed for the radius

FIG 25 Absence of forearms Small fragment of radius on left, no fragment on right Rudimentary phalanx present on right

ABSENCE OF FOREARM

In congenital absence of the forearm (Fig 25) a prosthesis must be applied It can be held on with a cuff above the con dyles instead of the usual shoulder strap

CONGENITAL SYNOSTOSIS OF UPPER END OF RADIUS AND ULNA

Several operations have been designed for this disability (Fig 26), the object of these being to secure pronation and supination The chief reason for failure of these is that ankylosis frequently recurs Probably the most reliable method is a resection of the head and upper end of the radius followed by physical therapy exercises after the tenth day [In resecting the radial head the tend ency to recurrence of the synostosis can be minimized by using an osteotome which is

sharp, thin, and narrow, severing the cortex just below the synostosis as near circumferentially as possible by successive short-cuts, and then using a thin curved osteotome to go through the synostosis A Gigli saw or a bone-cutting forceps are not advisable because of the bone dust or small bone fragments which may be left in the tissues Any splintering of bone is disadvantageous

Fig 26 Congenital synostosis, both bones of forearm

Fig 27 Congenital absence of elbow joint, left

Lavage of the wound after the resection, followed by superficial cauterization of all raw bone surfaces and edges, has seemed advantageous The approach from the postero-external aspect, involving minimal soft part damage, has seemed advisable in attempting to decrease the tendency to new bone formation and recurrence of the synostosis Kellogg Speed has recently devised a metal cup to fit over the end of the radius after resection of the radial head, with apparent success in a few cases, but the method has not been extensively enough used at present for general adoption See Fractures of the Radial Head, Smith, Chapter 31 —Ed]

DISLOCATION OF HEAD OF RADIUS

This may occur alone or be associated with congenital shortening of the ulna or absence of part of the ulna The treatment for the short ulna has been described In simple luxation of the head of the radius, the head can often be replaced, and if it can the arm is kept in acute flexion until the radial head remains in its normal position In intractable cases the head may be held in place by means of a fascial loop placed around the radial neck, the two ends of which are sutured to the posterior surface of the lateral humeral condyle [See Chapter 31 for procedure —Ed] If this fails the ob-

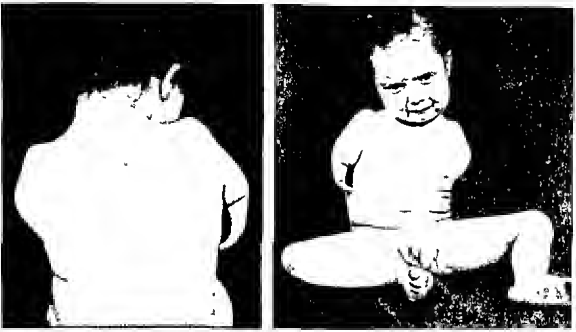


FIG. 28 Congenital absence of left humerus, right forearm, rudimentary finger.

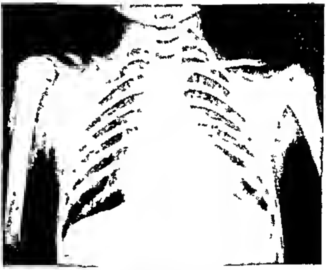


FIG. 29. (*Left*) Dislocation of sternal end of clavicle
FIG. 30. (*Right*) Cleidocranial dysostosis.

structing bead may be removed [See Chapter 31 for procedure —Ed]

CONGENITAL ANKYLOSIS OF ELBOW

This condition is very rare (Fig 27) In one sided disabilities surgery (arthroplasty) may be elected by the parents In double cases, arthroplasty is definitely indicated [See Chapter 15 for procedure —Ed]

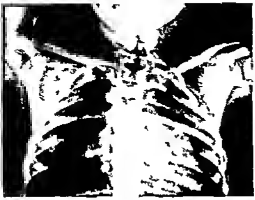



Fig 31 (*Left*) Congenital elevation of scapula
Fig 32 (*Right*) X ray of wire traction congenital elevation of scapula

ABSENCE OF HUMERUS

Absence of the humerus (Fig 28) may be partial or complete In a complete absence a hand or part of a hand or a finger may be attached There is no surgical treatment except the application of an artificial limb In partial absence of the humerus, bone grafting may be resorted to in order to give a more stable arm, but usually no treatment is indicated

ABSENCE OF SHOULDER GIRDLE

Absence of the shoulder girdle is very rare and is associated with loss of the upper extremity The treatment is an artificial limb

CLAVICLE

Congenital dislocation or subluxation of the sternal end of the clavicle (Fig 29) is associated with a posterior bowing of the inner third When recognized in early child hood, a figure of eight shoulder strap worn for a long period of time is frequently effica cious Later in life it will be necessary to correct the bow of the clavicle by osteotomy or the dislocation cannot be reduced The sternal end of the clavicle can then be sutured in place by means of fascial sutures

[The sternal end of the clavicle for an inch or more can be excised in these cases in later life if dislocation remains chronic or is recurrent and produces symptoms It is a simple procedure allows rapid resumption of function, is apparently effective, and pro duces no noticeable deformity Frazer Gurd has called attention to the simplicity of ex cision of the outer or inner ends of the clavicle for dislocations or arthritic affec tions In adult life or in late adolescence no deformity or disability results from excision of all or part of the clavicle In the young and growing child the procedures here ad vocated may be more desirable reserving resection for later in life —Ed]

CLEIDOCRANIAL DYSOSTOSIS

This condition (Fig 30) usually persists throughout life, but as in most conditions of this sort there is a fibrous band connect ing the two fragments A figure of-eight shoulder brace will help to prevent the for-

ward droop of the shoulders and should be worn throughout the period of growth

SCAPULA—SPRENGEL'S DEFORMITY

Sprengel's deformity is treated surgically There are four main types

1 Congenital elevation of the scapula existing alone (Fig 31)

2 There may be a fibrous band extending from the upper part of the vertebral border of the scapula to one of the lower spinous processes

3 The bridge may be bony with a pseud arthrosis between it and the vertebra

4 The bridge may be solidly connected from the scapula to the vertebral spinous process

Treatment

1 Remove the connecting bridge

2 Remove the supraspinatus process of the scapula submuscularly

3 Drill a hole through the center of the spine of the scapula and thread two loops of dental phospho bronze wire through this hole A second incision one inch long is made two inches below the inferior angle of the scapula and the four ends of wire are pulled down under the deep fascia overlying the scapula, emerging at the lower wound These loose ends are fastened together and protrude through the dressing A plaster spica is then applied from the toes on the affected side up to the axilla The back of the cast is cut away and downward traction is applied from a metal ring, incorporated in the leg of the cast, to the bronze wires

Fig 33 Result, two and a half years postoperative Spina bifida of cervical spine

A spring balance scale pulling at six pounds is sufficient to pull the scapula down It takes from four to six weeks to accomplish this (Fig 32)

At the end of this period a third incision four inches long is made over the mid dorsal spine slightly lateral to the spinous processes and opposite the second incision A generous bundle of muscle fibers of the erector spinae group and deep fascia are dissected free from above downward and divided transversely at the upper end This upper end is sutured to the lower angle of the scapula in order to keep it from sliding upward (Fig 33)

ABSENCE OF MUSCLES IN UPPER EXTREMITY

Absence of the pectoralis major occurs and needs no treatment Absence of the rhomboids causes severe round shoulders

and can be helped by making a slot one inch long in each vertebral border of the scapula and connecting the slots by means of a wide strip of fascia lata When pulling the scapulae together the surgeon must be careful that he does not use great tension as the patient is apt to have difficulty in breathing

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2

Congenital Deformities of Spine

Joseph A Freiberg M D

For the numerous and varied congenital deformities of the spine, surgical indications are somewbat limited There are two purposes or indications for surgery (1) Urgent interference to prevent complications, (2) surgical interference to prevent increasing deformities dependent upon the osseous anomalies and to stabilize an inherent instability of tbe spine due to the osseous anomalies Various combinations of congenital deformities or anomalies are possible and various degrees of severity or deficiency due to anomalies or ossification may be seen Many of the congenital osseous anomalies of the spine have no clinical significance excepting as they may contribute to an inherent instability of the spine which then becomes the seat of a disturbance following lesser injuries, or become symptom producing associated with a debilitative disease accompanied by a period of muscular insufficiency

As the various types of anomalies of ossification and osseous defects are too numerous to list, only those witb therapeutic indications will be discussed and these will be separated under individual headings

SPINA BIFIDA

Spina bifida may vary from the single so-called spina bifida occulta involving a single arcus and failure of fusion of the lamina to form a spinous process (Fig 34), to a very extensive neural arch defect There is no treatment indicated for these conditions unless they are associated with other anomalies causing symptoms of instability Spina bifida alone is an inadequate basis as a cause for instability or treatment thereof In the more extensive lesions of two or more vertebrae a large defect may be found in the arcus of the several vertebrae involved Associated witb tbis defect may be a lipoma a meningocele or a myelomeningocele, containing numerous nerves attached to the inner surface of the arachnoid membrane As the meningocele contains cerebrospinal fluid there may be sufficient tension in the meningocele to cause a definite tbinning of the overlying skin Unless there is danger of rupture of the meningocele and the overlying skin or the tumor mass is so large that it becomes a physical or mechanical problem, no therapy is indicated In the newborn, on occasion conservative therapy consisting of warm pads held in place by elastic dressing or adhesive tape will prevent a breaking down of the skin until such a time as surgery is indicated While hydrocephalus not uncommonly develops in association with spina bifida and meningocele, it very frequently develops following the resection of the meningocele On the assumption, based on numerous references substantiating this hypothesis that the meningeal sac presents a safety factor in allowing absorption of cerebrospinal fluid, resection of the sac is ordinarily contraindicated The problem is a neuro-

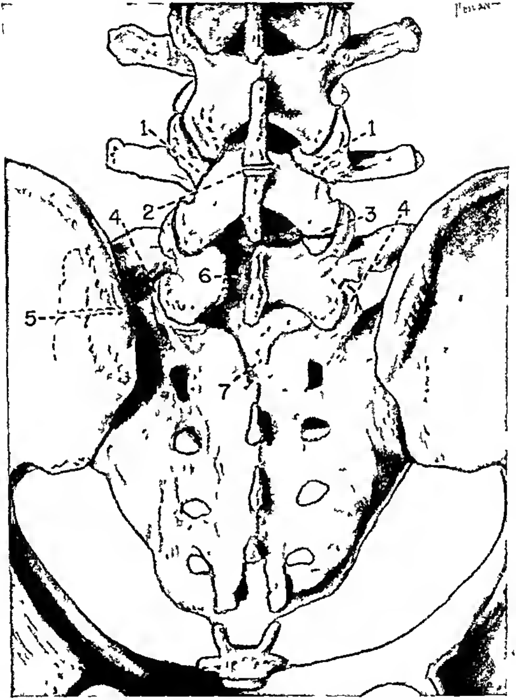

FIG 34 Some less obvious anomalies of spine

1 Bilateral isthmus defects or congenital fractures (third lumbar arcus)
2. Impingement of spinous processes (third and fourth lumbar vertebrae)
3 Fissure defect or fracture (right inferior articular process fourth lumbar vertebra)
4 Tropism or inborn asymmetrical development of zygapophyses (lumbosacral joints)
5 Sacralization of left fifth lumbar vertebral transverse process with pseudarthrosis
6 7 Spina bifida occulta (fifth lumbar and first sacral segment)

logic surgical one [For the treatment of back disability consequent on the lesser lesions see Low back Pain, Freiberg, Chapter 9 —Ed]

CONGENITAL DEFORMITIES OF ARCUS OF VERTEBRA, EXCLUDING SPINA BIFIDA PROPER

Not always easy of recognition, and far from infrequent in occurrence congenital defects or failure of fusion of the pedicle isthmus or the laminae are lesions capable of producing definite symptoms Whereas these lesions may be of traumatic origin, or of congenital origin, the present concept of trauma at the time of delivery or in infancy is generally accepted, following the thorough study of these lesions in infants and new born by Dr H H Hitchcock [1] These lesions are most frequently seen in the lumbar or lumbosacral area of the spine The need for treatment, conservative or surgical depends upon the symptoms associated with the lesion The exception to the preceding statement is the presence of bilateral pedicle or isthmus defects (Fig 34) which allow anterior posterior disalignment of the spine commonly called spondylolisthesis In the presence of a frank spondylolisthesis with disalignment in a young individual or in a vigorous adult, fixation by either external appliance or surgical fusion is indicated The finding of a spondylolysis without displacement but capable of resulting in a true spondylolisthesis warrants close observation of the patient in the absence of symptoms In the presence of symptoms the therapy is the same as for spondylolisthesis [See Freiberg Low back Pain, Chapter 9 —Ed]

CONGENITAL SCOLIOSIS

A third type of congenital deformity of the spine not infrequently seen is a true structural scoliosis dependent upon the presence of one or more hemivertebrae The deformity is due to a failure of development of one lateral half of a vertebra, and a consequent lateral disalignment or curvature In the presence of more than one hemivertebra on opposite sides the deformity may not be visible externally Treatment of these deformities depends upon the structural alignment of the spine as a whole, and on whether or not the lesion interferes with the function of the spine Whereas resection of the hemivertebra has been proposed and done (Compere,[2] et al) it is generally considered that this surgical procedure *is unnecessarily hazardous* The deformity may be controlled either by external support and muscle training or by internal fixation by spinal fusion In the infant and young child no treatment is indicated if the deformity is not severe If the deformity is moderately severe in the infant, a plaster bed is made to hold the spine in a corrected position The child is kept in this plaster bed for a period of many months (Ghormley[3]) When the walking age is reached, if the deformity is not severe, either a rigid removable support such as a split plaster cast is made or a corrective type of corset is applied In the older child, if the deformity has assumed a definite prominence, treatment is similar to that carried out in other types of structural scoliosis [Scoliosis, Von Lackum, Chapter 6 —Ed]

CONGENITAL FUSION OF VERTEBRAE

A fourth type of congenital deformity of the spine seen not infrequently is a congenital fusion of one or more bodies of the vertebrae As under ordinary circumstances this lesion offers no probabilities of producing symptoms or deformity, no therapy is indicated The lesion is recognized commonly in x rays taken following a lesser trauma or for some other condition

When there is a structural mechanical insufficiency of the spine due to a congenital deformity and conservative therapy does not suffice, a spinal fusion operation is done The type of fusion depends upon the character of the lesion [For description of the operation see Low back Pain, Chap 9 —Ed]

KLIPPEL-FEIL SYNDROME

Congenital deformities of the spine occur most frequently in the cervicodorsal and lumbosacral areas Infrequently, combined arcus and vertebral body anomalies occur in the cervicodorsal area accompanied by marked loss of length of the cervical spine and absent or deficient zygapophyses Associated with this type deformity are apparently highly situated scapulae As this deformity Klippel Feil syndrome is an inherent spine deficiency with limited motion no therapy is indicated Rarely instability of the cervical spine causes nerve root irritation Under these conditions stabilization by external fixation or spine fusion is indicated

ZYGAPOPHYSEAL DEFORMITIES

Zygapophyseal or articular process deformities are of three types

1 Insufficient articular areas with instability and susceptibility to mechanical strain

2 Tropism or a disalignment from the normal axis of one or both zygapophyses (see Fig 34)

3 Fissure delect or congenital fracture through an inferior articular process (see Fig 34)

Zygapophyseal deformities of Type 1 are seen most often as extensive or multiple lesions The treatment is supportive by the use of braces or, if necessary, by a spinal fusion operation

In zygapophyseal tropism rarely noted elsewhere than in the lumbosacral spine treatment depends upon the symptoms This lesion is one of several resulting in so-called unstable lumbosacral spines and the management is discussed under Low back Pain in Chapter 9

Fissure defects may occur anywhere in the spine but are found most frequently in the lumbar segment These lesions are often mistaken for fractures indeed the differentiation often depends upon the history given by the patient If there are accompanying symptoms treatment is primarily conservative postural training and temporary brace, but occasionally internal fixation by spinal fusion is necessary for relief

CONGENITAL DEFORMITIES OF PELVIS

Congenital deformities of the pelvis do not frequently present a surgical problem The most common congenital deformity is that of an asymmetrical development of the two innominate bones This lesion is often associated with a co-existing asymmetrical development of the lower extremities An asymmetric or underdevelopment of one of the innominate bones is often accompanied by an inequality in leg length The existing problem then is an equalization of leg length This may be accomplished by the use of elevation of the shoe or if the inequality in leg length is great—more than 1½ inches in a child or vigorous young adult—one of the leg length equalizing surgical procedures may be indicated [See Anterior Poliomyelitis Chapter 7 —Ed]

There are several types of congenital abnormalities of the acetabulum these varying according to the site of the anomaly either in the ilium or the ischium or the pubic portion of the acetabulum The most common deformities are those in the iliac portion of the acetabulum and are ordinarily associated with subluxation or congenital dislocation of the hip The problem of therapy, therefore rests primarily with the management of the congenital dislocation of the hip [Congenital Dislocation of the Hip Brewster Chapter 4 —Ed]

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3

Congenital Deformities of Lower Extremity

J H KITE, M D

Congenital deformities of the lower extremity may be divided into (1) hypertrophic and (2) hypoplastic anomalies Each of these may be divided into (a) symmetrical and (b) asymmetrical deformities

CONGENITAL HYPERTROPHIC ANOMALIES

SYMMETRICAL ENLARGEMENTS

Enlargement of Both Legs (Milroy s Chronic Hereditary Edema[1]) In 21 of Milroy s 22 patients the swelling was present at birth He states that chronic hereditary edema is a firm edema limited in extent to the toes or to a part or the whole of one or both feet, or of one or both legs It never extends above Poupart's ligament It is not painful or tender, and is without constitutional symptoms The cause is unknown Hereditary transmission is definite The edema is permanent although it subsides to some extent on rest in bed It occurs in both sexes It does not affect the life span

This is a very rare condition (Fig 35) Bed rest for excessive swelling and provision for proper shoes is the only therapy indicated

Hemi hypertrophy Symmetrical hypertrophy may be limited to the enlargement of one leg or one foot (Fig 36) This, again, is rare Often the deformity warrants no surgical procedure, and attention to foot wear is the only treatment needed When the hypertrophy involves the entire extremity, the growth of the bones can best be controlled by arrest of the epiphyseal growth at the proper age, if the patient is seen during the growing period If seen after growth has ceased, the length of the legs might be equalized by shortening the femur by one of the plastic operations [See leg equalizing procedures under Anterior Poliomyelitis, Cleveland, Chapter 7 —Ed]

ASYMMETRICAL ENLARGEMENTS

Enlargements of Toes An asymmetrical hypertrophy is a congenital enlargement of a part of an extremity, as enlargement of the toes, or of a part of the foot At times the deformity is so marked that surgery is necessary Some of these enlargements are due to lipoma which has been present since birth (Fig 37) In most cases the hypertrophy must be reduced by removing the hypertrophied tissue so as to restore the part to as near normal as possible When this cannot be done it is best to remove the enlarged part (Fig 38) When the parents are opposed to operation, and the hypertrophy involves the toes, a special shoe may be made (Fig 39), but special shoes are usually too expensive for most patients An amputation of the enlarged part, if it is a toe, is then the method of choice

Asymmetrical congenital hypertrophy

may be due to a numerical increase in the parts as in polydactylism (Figs 49 95 96

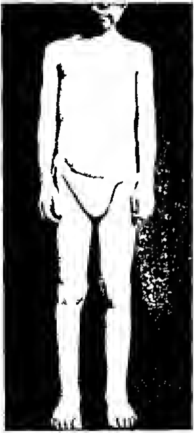


Fig 35 Milroy s chronic hereditary edema Boy aged 13 with congenital hypertrophy of both lower extremities Enlargement of both legs from knees down In each thigh is enlargement of saphenous vein which feels firm as though thrombosed There is a pitting edema of lower legs and feet Lower legs have a cylindrical rather than a normal outline There is considerable edema over dorsum of each foot Patient wears regular shoes and pursues normal activities

and 97) In such cases the extra parts should be removed

Special plastic procedures are rarely indicated

CONGENITAL HYPOPLASTIC ANOMALIES

Symmetrical Atrophy

Congenital hypoplastic anomalies occasionally show a symmetrical shortening of one extremity (Fig 40) but this is rare compared to the asymmetrical deformities

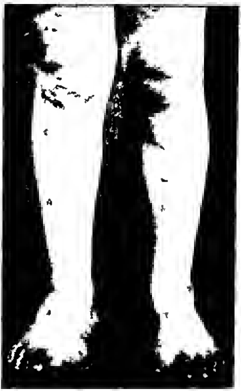


Fig 36 Congenital hypertrophy of foot Left is considered normal Great toe on right is separated from enlarged second toe Consistency of soft parts seems normal with no evidence of tumor as is sometimes seen The only difficulty is necessity of buying shoes of different sizes to fit these feet

The hypoplastic anomalities are seldom corrected by surgery The difference in length might be equalized by an epiphyseal arrest on the normal leg or by shortening the longer leg [For procedure see Chapter 7 — Ed] By far the larger number are treated by some type of extension apparatus

A B C D

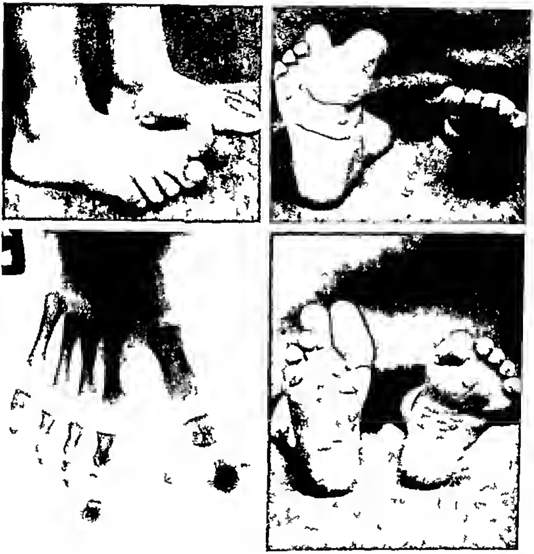
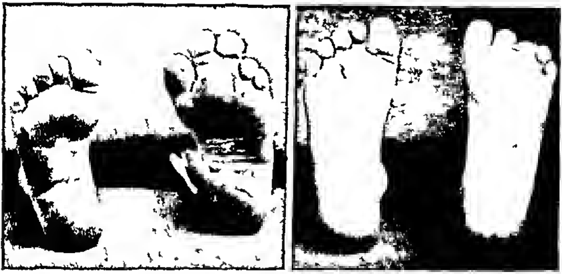


FIG 37 Congenital hypertrophy of first and second toes due to lipoma At birth great toe and second toe on right were abnormally large These grew more than the other toes so that the hypertrophy increased making it impossible to wear ordinary shoes (A B C) Voluminous tissue between toes was eliminated by dissecting out this thick mass of fatty tissue diagnosed by pathologist as simple lipoma After operation (D) patient was able to wear shoes with very little discomfort Nine years after operation the two enlarged toes on right bear about same relation to foot as in (D)

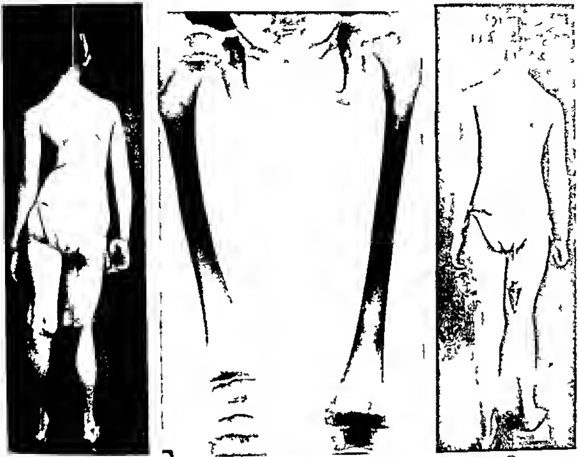


A B

Fig. 38 Congenital hypertrophy of second and third toes, left At birth, left second and third toes were enlarged Patient continued to burst toe out of left shoe (A) Hypertrophied distal phalanges of second and third toes were amputated, and excess tissue removed (B) Patient could then wear shoes in comfort

A B C

Fig. 39 Congenital hypertrophy of toes This girl was born with enlarged left second and third toes (A), which became larger after she began walking to school She was unable to wear even tennis shoes in comfort She was first treated by special shoes (B), but these proved too expensive The toes were then amputated (C) Several years later she could wear a size 7 slipper on each foot For x-ray of this patient see Fig 98



A B C

Fig 40 Congenital atrophy of leg symmetrical At birth right leg was smaller than left, although normal in outline X ray made at age four weeks showed right femur to be nearly 2 cm shorter than left Hips were not dislocated

At age five right leg was 5 cm shorter than left (A) giving a total curve to spine At this time right x ray was 4 9 cm shorter than left, but normal in outline (B) It was necessary to apply a lift under right foot to correct spinal curve (C) A shoe with a cork lift was applied which also helped to overcome the limp

At age seven an epiphyseal arrest was done on normal left femur—probably done at too early an age The difference in length will be equalized before she is grown and the normal left leg may become shorter than right See Chapter 7 for method of computing proper time for growth arrest

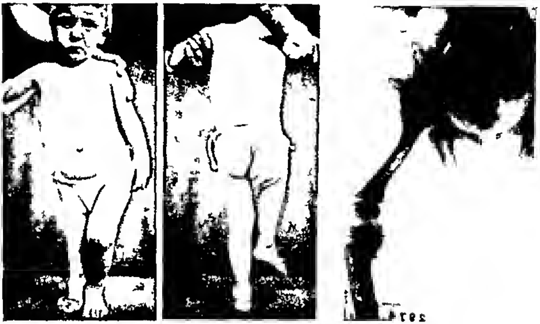
Asymmetrical Atrophy

Asymmetrical congenital hypoplastic anomalies of the lower extremity may be due to a partial or complete absence of the (1) femur, (2) fibula, (3) tibia or to a (4) congenital amputation

Anomalies of Femur A congenital anomaly of one of the long bones of the leg is accompanied usually by other congenital deformities frequently of the same leg This is particularly true of the femur The defect in the femur is in the upper half in most cases (Figs 41 and 42) At times when there is involvement of the lower part of the femur the femur is synostosed to the upper epiphysis of the tibia (Fig 43) and (Fig 45 C) A complete absence of the femur is rare and this diagnosis should not be made before the age of ten There may be a rudimentary epiphysis which will not show in the early x rays, which will appear by the age of ten at one end or the other

The most common defect associated with partial absence of the femur is absence of patella and fibula of the same leg (Fig 43)

It is an interesting fact that the mild congenital deformities such as syndactylism or polydactylism show a marked familiar tendency, while these major deformities seldom ever give a hereditary history



A B C

Fig 41 Congenital atrophy of leg asymmetrical absence of upper end of femur At birth right leg was shorter than left At age three right measured 12 cm shorter (A and B) She was able to walk and bear weight on right leg but limped badly X ray showed the shortening to have occurred in upper end of right femur, which had no head Proximal end of femur was resting against side of ilium (C) Both tibiae measured the same length An extension apparatus was applied

Anomalies of Fibula. Congenital defects of the fibula are three times as frequent as those of the femur Freund's classification of deformities of the fibula follows

- A Complete absence of fibula
- B Partial absence of fibula
  - 1 Lower part absent
  - 2 Upper part absent
  - 3 Diaphysis deficient upper and lower ends present
- C Hypoplasia of fibula

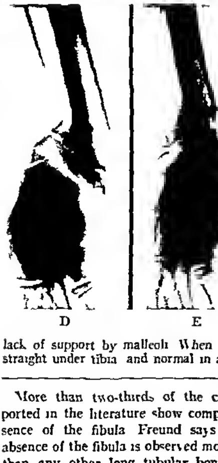
A C

B

Fig 42 Congenital absence of upper two thirds of left femur This patient has multiple deformities with ankylosis of right elbow and shortening of fore arm One finger is stiff and one thumb is dangling from the hand (A) There is congenital absence of most of left fore arm and hand with ankylosed elbow She has a congenital coxa vara of right hip and absence of most of upper part of left femur (B) Right femur is also shorter than normal Right leg measures 42 0 cm left 27 5 cm giving 14 5 cm shortening on left She was fitted with an extension apparatus so that she might *sit on top of the ring and walk without* having to flex right knee to compensate for shortening on left (C)

Fig 43 Congenital synostosis of knee congenital absence of fibula Patient was born with a deformity of right hand and both feet Feet were very small and were amputated elsewhere She is walking with braces When she was small an unsuc cessful attempt was made to straighten the knee The chief handicap to wearing braces is flexion deformity of right knee There is congenital absence of patella *also absence of fibula* The *two* epiphyses have fused and a bridge of bone has grown across knee posteriorly In order that patient might wear an artificial leg flexion deformity was corrected by a cuneiform osteotomy of knee without injury to epiphyseal lines

A B C



D E

Fig 44 Congenital absence of part of fibula with valgus deformity of ankle At birth right foot was rolled out from under leg When first seen at age eight, she walked badly and ran right foot over in a marked valgus position (A and B) There was absence of lower portion of shaft of fibula (D) Lower epiphysis was present but did not keep astragalus from rolling over as entire epiphyseal line of tibia was tilted lateralward at an angle of about 45° Superior articular surface of astragalus was at a right angle with midline of tibia (If midline of tibia were projected it would fall medial to foot)

Two operations were done First, a cuneiform osteotomy was done near lower end of tibia making an incision just above epiphyseal line and parallel with it and another higher up removing a wedge-shaped portion of bone with the base on the medial side When the cut surfaces came together ankle was straight under tibia (E) Later, a Hoke flatfoot stabilization was done on the foot A brace was worn for a year to protect ankle because of lack of support by malleoli When seen last, eight months after operation, right foot was straight under tibia and normal in appearance (C)

More than two-thirds of the cases reported in the literature show complete absence of the fibula Freund says "Total absence of the fibula is observed more often than any other long tubular bone The total absence of the fibula should not be accepted as a fact until after the fifth year, as an epiphysis might develop at this time, when the previous early x ray showed nothing

Loss of the upper end of the fibula causes little loss of function When the lower part of the fibula is defective, the support of the lateral malleolus is lost, and the foot turns out into valgus If so, (a) a brace may be worn to hold the foot straight under the tibia, or (b) a cuneiform osteotomy may be done on the lower end of the tibia, to level the articular surface between tibia and astragalus (Fig 44) In addition, it may be necessary to do a flatfoot stabiliza tion as was done for patient shown in Fig 44, or (c) the astragalus may be fused to the tibia When the foot is clubbed or shows marked deformity the treatment *is often* directed first to the correction of the foot deformity (Fig 45), and later the flexion or knock knee deformity may be corrected by an osteotomy of the tibia if necessary as was done in this last case A brace may still be necessary to support the knee and ankle

Volkmann in 1872 described two cases of congenital luxation outward of the ankle associated with absence of the upper four fifths of the fibula, and *also* some shorten ing of the tibia I have a similar case in father and son The father shows a con genital hypoplasia of the fibula The defect seems to be in the diaphysis of the fibula while the ends are well developed (Fig 46) The distal end of the fibula gives some support on the lateral side of the astragalus but this support is so deficient that the feet turn in a marked flatfoot position There is an abnormal shortening of each tibia with knock knee deformity The son shows still more shortness of the lower legs, the knock knee deformity, and the extreme flatfoot deformity (Fig 47 A) The x ray picture shows a complete *absence of* the fibula (Fig 47 B and C), but a center of ossifica tion may appear later The son has con genital dislocation of the knees, which the father did not have Braces will be applied when the child is old enough to begin walk-ing

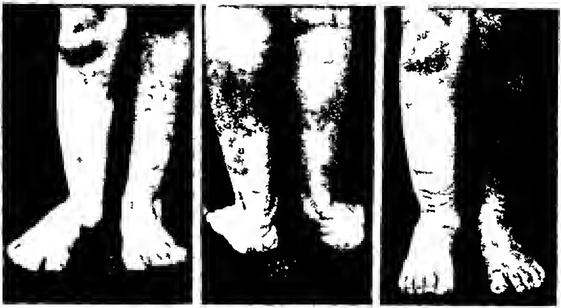
Anomalies of Tibia Deformities of the tibia are frequently associated with ab sence of the fibula One of the most fre-quent findings is an anterior and sometimes a medial bowing of the shaft of the tibia resulting in thickening and shortening of the bone (*Fig 48*) The *point of angulation* is most frequently at or a little above the junction of the middle and lower thirds Fre quently there is a scar or dimple over the apex of the curve The x ray picture shows a marked thickening of the bone on the concave side of the curve This sclerosis may involve the entire thickness of the bone (Fig 48 B)

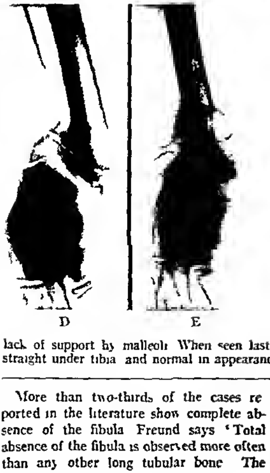
In *cases with bowing of the tibia there is* a short heel cord and the foot is forced down in equinus The tendon is tighter and more resistant to treatment than in con genital clubfoot Sometimes there is no real tendon, but a mass of tight fibrous tissue which is difficult to get to yield when an attempt is made to lengthen it There is a great tendency for this deformity to recur The foot should therefore be held for a long time in plaster in dorsiflexion after the Achilles tendon has been lengthened, and the plasters wedged in dorsiflexion

At times the *anterior* and *lateral* bowing of the tibia can be lessened by a series of casts and wedgings followed by a corrective brace Very little force should be used in order not to fracture the tibia

These bones are similar in appearance to the bones seen in congenital pseudarthrosis before the tibia has fractured It is not often that a tibia is seen in congenital pseu darthrosis before it has fractured but there are several shown below (Figs 66 and 67) Because of the difficulty in getting such bones to unite after they are broken, they should be protected *from fracture* and an operation should not be undertaken lightly (*Fig 70*) *When it is necessary to correct* the deformity, a long oblique osteotomy should be done (*Fig 48 C*), so as to *increase* the area of raw bone for union In addition to this, better external fixation should be used than would ordinarily be used for an

A B C





D E

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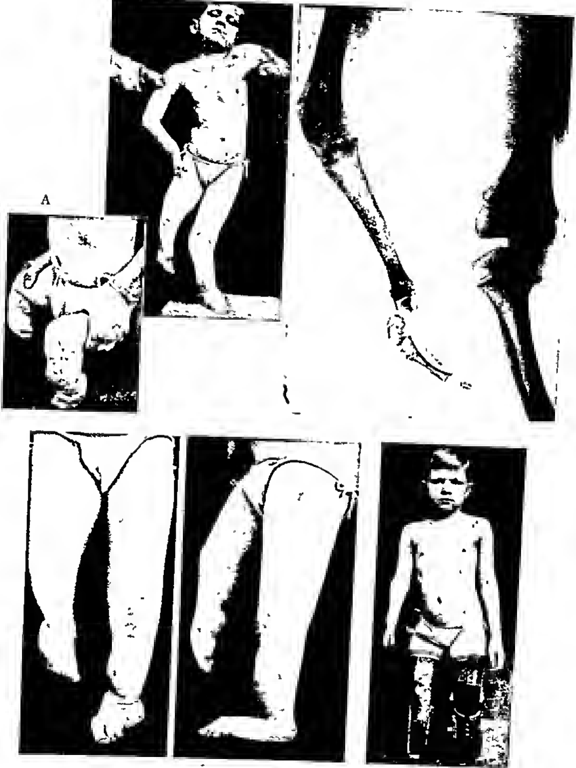
B C

A



D E F

FIG. 45. For legend see p. 33.

osteotomy or fracture of normal bone The plaster should extend from the toes not only to the upper thigh, but in small children should go around the pelvis as a spica, as is recommended for external fixation after bone graft for congenital pseudarthrosis When this is done union has always been obtained in my personal series

Associated with the deformity of the tibia is a congenital absence of some of the bones of the foot, or of a part of the foot (Fig 48 E) Syndactylism is also a frequent finding and, at times, polydactylism (Fig 49)

Absence of a part or all of the tibia is a rare deformity as compared with the fibula [3] With it we frequently see other deformities such as dislocation of the hip (Fig 49), shortening of the femur, absence of the fibula, clubfoot deformity, absence of one or more tarsals, metatarsals or toes The fibula is usually shorter and thicker When the upper end of the tibia is absent, it is impossible for the fibula to form a weight bearing joint with the femur (Fig 49, *top*) Frequently the fragment at the lower end does not develop sufficiently well to act as a medial malleolus This portion may retain its embryonal form and be the same size as the fibula, and be useless as a support

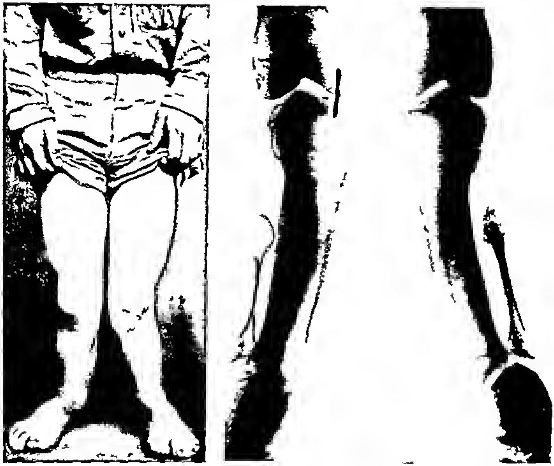
Only one case of total absence of the tibia has been encountered in over 7,500 orthopedic patients (Fig 50). Until 1877 amputation was the only mode of treatment In that year Albert implanted the fibula into the femur It is very difficult to get the knee straight, even when most of the posterior structures are cut, and even when this is accomplished, and the fibula grafted to the femur, nonunion frequently results, with a poor weight bearing extremity There is often a dislocation at the ankle also, and if the astragalus could be fused to the fibula the extremity would still be very short and the patient would need an extension apparatus of some kind to compensate for the shortening For this reason many of these patients are treated with braces and extension apparatus instead of by surgery When there is fixed flexion deformity of the knee this can be used to a good advantage to carry the extension apparatus (Fig 50 D and E)

Another variation in congenital anomalies of the tibia which we see very rarely is a case in which the tibia and fibula are the same size (Fig 51) Freund says

> Up to the third month of life the fibula is evenly developed with the tibia that is, it is relatively much stronger than the latter In cases in which there is congenital defect of the tibia, it preserves its early thickness and appears hyperplastic Thus, despite the fact that

FIG 45 Congenital absence of fibula bilateral multiple deformities Patient also has an absence of two fingers on right hand, with atrophy and fusion of the other two fingers absence of some carpal bones, dislocation of head of right radius, a short right femur synostosis of right knee with fusion in a flexed position, absence of patella, equinovarus deformity of right foot, and absence of the lateral two toes, with fusion of the other two Left lower leg shows a marked anterior bowing of tibia, with deep dimple over point of angulation There is an equinovarus deformity of this foot with valgus deformity in ankle, since astragalus articulates with tibia only There is the same absence of the two lateral toes on the left with fusion of second and third

Treatment was begun at age of one year First clubfoot deformity on left was corrected so that patient might be able to bear weight on this one leg (A) Equinus deformity was more difficult to correct than in an ordinary clubfoot The Achilles tendon had to be lengthened [For procedure, see Chapter 42] Braces and extension apparatus were worn for seven years Patient was re admitted at age eight (B), because of marked knock knee deformity on left, the main weight bearing leg X ray shows knock knee deformity and synostosis of right knee (C) A high tibia osteotomy was done to correct deformity (D and E) This restored alignment of left leg and made it a good weight bearing extremity A brace was needed to stabilize left knee and foot since there was an absence of fibula With an extension apparatus on right (F), patient is able to walk actively without crutches



A B

FIG 46 Congenital hypoplasia of fibula associated with congenital shortening of tibia Patient has always walked on medial side of his feet with feet turned out in a marked flatfoot position (A) Tibias are very short as compared to femurs Trunk and arms are well developed There is marked knock knee deformity Tibias are unusually thick and broad (B), but form a fairly stable articulation at knee and ankle because fibulas give some support on lateral side of astragalus Fibulas are about half the length of the shortened tibias Each end seems to be well formed It seems to be the shaft which is deficient

A

B

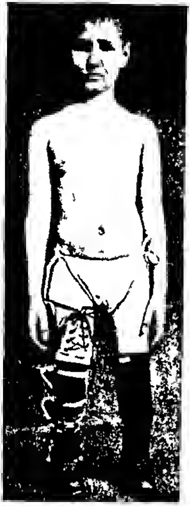
C

Fig 47 Congenital absence of fibulae, associated with congenital shortening of tibiae congenital dislocation of both knees The most striking thing in this 13 month old child is the shortness of his legs (A) somewhat like those of his father (Fig 46) He has a normally developed trunk and arms Every time he kicks his legs the knees can be seen to dislocate a grating noise can be heard, and a crepitus can be felt When either knee is flexed tibia slips back under femur, and when knee is extended tibia slips forward anterior to femur (C) There is a knock knee deformity so that with knees touching ankles are separated 8 cm Feet turn out in valgus because there is no fibula to support lateral border of astragalus Foot turns over to such an extent that little toes rest against lateral border of lower leg On x ray film femurs measure 13 4 cm and tibiae only 5 5 cm (B)

A B C

FIG 48 Anterior bowing of tibiae congenital absence of fibulae Both lower legs are very short as compared to thighs (A) There is a bilateral absence of each fibula Each tibia shows an anterior and medial bowing X ray at age two shows, in addition to these deformities an absence of each astragalus, and each cuboid (B) There are three toes and three metatarsals on right, two toes and two metatarsals on left Each foot is in a marked valgus position There is a bilateral knock knee deformity Tibiae are thick and short and show increased density at point of angulation

A long oblique osteotomy was done on each tibia to correct angulation (C)



D

E

Fig 48 (*Continued*) Flatfoot deformity was corrected by a series of plasters and wedgings and a brace was worn on right to keep knee in full extension (D) An x ray made seven years after operation shows a tibia presenting nearly normal bone structure (E) Astragalus is still absent at age nine Patient when last seen was walking without braces or any form of support, placing his feet straight in front of him, and walking in normal manner

FIG 49 Congenital absence of upper part of tibia. Patient also has a congenital dislocation of right hip with a deep false acetabulum on side of ilium (*lower illustration*) An unsuccessful attempt was made to reduce this deformity Congenital absence of upper half of shaft and upper epiphysis of tibia (*upper illustration*) Patient was four years old when x-ray was made Remaining portion of tibia is no larger in diameter than fibula. Fibula is thicker than might be expected There is a dislocation of joints at knee and ankle so that weight bearing is impossible Foot is turned in extreme varus because there is no support on medial side of ankle. Foot also presents forefoot adduction, typical of a clubfoot. There are eight metatarsals and nine toes, there being an extra toe between the first and second. No great toe present. Second and third toes fused. Patient learned to walk on crutches and opposite normal foot. With extreme atrophy, and dislocation of all three joints in this leg, no attempt was made to make it weight-bearing Later an extension apparatus may be worn.

the deformities have to be considered as caused by faulty anlage of the extremities, certain embryonic stages may be recognized in different types of defects.

The patient shown in Fig. 51 is the only one in my series Both the tibia and fibula are about the same diameter and about the same length in both legs If the foot were not attached it would be difficult to tell one from the other This case had many associated congenital deformities

Congenital Amputations Finally, asymmetrical congenital hypoplastic anomalies might be illustrated by congenital amputations (Fig. 52). These may be unilateral or bilateral, and vary from the loss of a small part of the foot to an absence of practically all of the extremity. Sometimes surgery is indicated to make a better weight-bearing stump, by doing a re-amputation Some simple type of extension apparatus should be used as soon as the child is old enough to walk, so that the remains of the leg may develop with use. When the child is grown, an artificial leg can be resorted to

CONGENITAL CONSTRICTIONS

Children are occasionally seen with deep circular depressions about the upper or lower extremities These seem to involve the skin and muscles down to the bone. From the appearance of these, it might be easy at times to imagine that these constrictions are the result of the umbilical cord being wrapped around the extremity (Fig 53) Frequently the parents will give this as an explanation of the deformity. This would not explain constrictures about fingers and toes (Fig. 54).

Congenital constrictions are seen once in about every 1500 orthopedic admissions in my series In every case in this series the child has had clubfeet (Fig 55), and also every one has had some deformity of the hands (Fig. 56). This deformity has consisted of an absence of some part of the hand or fingers Often syndactylism is present

Treatment consists of separating the

fingers by plastic surgery The clubfoot deformity has been corrected by plaster and wedgings As a rule these feet are more difficult to correct than the average club foot For cosmetic reasons the deep band can be excised and the soft parts and skin drawn together with sutures The results are not so good as might be expected Most times the child does not seem to be inconvenienced by the constrictions, and for this reason they are usually left alone, and the treatment directed toward correcting the clubfoot and any other deformities that may be present

CONGENITAL CONTRACTURES

Congenital contractures may involve any of the joints They are usually associated with other congenital deformities They often involve the shoulder, elbow, hip knee and at times involve the hand and foot Usually there is a limitation of motion in the joint, limiting full extension There is frequently redundant skin going across the flexure of the joint (Fig 57) The restriction of motion in these joints is quite different from the restriction of motion in arthrogryposis multiplex congenita. In this latter condition the motion is free for a part of the range of motion and then it is suddenly stopped as if there were bony blocking or very strong adhesions In these cases with *congenital contractures the motion is* limited by the elastic stretch of the skin and soft parts These cases of congenital constrictions are not associated with club feet, while arthrogryposis multiplex congenita, on the other hand is associated with congenital clubfeet

Treatment consists in gradually stretching the flexed joints until they come into full extension Many times this can be done by plaster and wedgings After they are in full extension, a retention splint or brace should be worn for a while to prevent a recurrence At times it is necessary to lengthen resistant tissue by some type of plastic operation

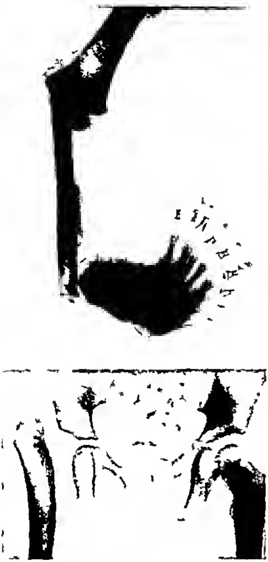
CONGENITAL BANDS

This condition may be similar to the last two conditions, but seems to differ enough to warrant a separate classification It is a rare condition, and only one case has been seen in more than 7500 orthopedic patients (Fig 58) At birth the leg affected was smaller and the foot was in equinus and there was a tendonlike band extending from the ischial tuberosity to the os calcis The band was divided at four places and the foot gradually stretched in dorsiflexion The equinus deformity was very difficult to correct, as might be expected when it is remembered that this was a congenital deformity The deformity, however, was corrected and the correction was retained

ACHONDROPLASIA

Achondroplasia is a condition of abnormal osteogenesis which produces a dwarf It begins in intra uterine life There is a deficient formation of cartilage with prompt conversion of cartilage into bone The long bones are stunted The centers of ossification for the epiphysis appear about the normal age and are regular in contour and internal structure There is no disturbance in the ossification of the metaphyses This condition may be found in several generations The arms and legs are short in contrast to the normally developing torso The *hand is short and broad and the fingers of equal length When these cases* present a bowleg deformity in infancy they may be mistaken for rickets (Fig 59) Rickets in x rays show decalcified bones with poorly ossified epiphysis, and coarse trabeculation Achondroplasia shows short, broad bones with normally dense shafts

Treatment There is nothing that can be done for the achondroplasia itself The bowleg deformity can be corrected by braces when seen early After about three years of age, as in rickets osteotomies are required to correct the bowleg deformity When an operation is needed a long oblique osteotomy is done on the tibia, beginning just



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ACHONDROPLASIA

Achondroplasia is a condition of abnormal osteogenesis which produces a dwarf It begins in intra uterine life There is a deficient formation of cartilage with prompt conversion of cartilage into bone The long bones are stunted The centers of ossification for the epiphysis appear about the normal age and are regular in contour and internal structure There is no disturbance in the ossification of the metaphyses This condition may be found in several generations The arms and legs are short in contrast to the normally developing torso The hand is short and broad and the fingers of equal length When these cases present a bowleg deformity in infancy they may be mistaken for rickets (Fig 59) Rickets in x rays show decalcified bones with poorly ossified epiphysis and coarse trabeculation Achondroplasia shows short, broad bones with normally dense shafts

Treatment There is nothing that can be done for the achondroplasia itself The bowleg deformity can be corrected by braces when seen early After about three years of age, as in rickets osteotomies are required to correct the bowleg deformity When an operation is needed a long oblique osteotomy is done on the tibia, beginning just

FIG 50 For legend see p 41

distal to the upper epiphyseal line and extending obliquely downward from the lateral to the medial side of the tibia When the shaft of the tibia has been completely divided, the upper end of the fibula should be greenstick fractured in order to remove any tension which might cause pressure sores under the plaster when the deformity is corrected This permits easy correction of the bowleg deformity as well as correction of the inward torsion, and affords a long area of new bone formation, which gives a solid union strong enough for weight bearing in six to eight weeks

CHONDRODYSTROPHIA FOETALIS

Ferguson[4] says

Conditions characterized by altered rate of growth of bone from cartilage are to be classed as chondrodystrophy Delayed growth of cartilage and of bone irregularly at the epiphyseal discs produces short broad bones, which are characteristic of chondrodystrophia foetalis There is always some degree of irregularity of the epiphyseal line and there may be marked deformity of outline and texture in the metaphyseal and epiphyseal regions

Brailsford[5] describes a number of similar cases under the term "chondro osteodystrophy,' and divides these into four classifications He says

In chondro osteodystrophy, which may also produce a dwarf skeleton, marked irregularities in ossification can be demonstrated at the metaphysis, but in achondroplasia after birth there is no evidence of departure from the normal One might say that whereas in achondroplasia there is an error in the Architect's plans, in chondro osteodystrophy the defects in stature are due to defective building material

The x rays show large gaps between the osseous nuclei in the epiphyses and the metaphysis These changes indicate defective ossification There are pressure deformities of these areas (Fig 60) In the case shown, there is a coxa vara in the right hip with a wide epiphyseal line which is perpendicular instead of transverse and at the right knee an absorption of lime salts on the medial side of the tibial metaphysis giving a knock knee deformity and a still more marked change in the lower end of the left femur The active stage of the d[illegible] trophy appears to cease when the epiphyseal lines fuse The pressure deformities rema[illegible] evidence that a dystrophy existed

Treatment There is nothing that can be done for the dystrophy itself Braces may be worn to help correct some of the deformities, and to prevent the deformity from increasing An osteotomy can be done through the defective bone with as good chance of union taking place as if it were normal bone There is a greater chance of one operation correcting the deformity if operation is postponed until the epiphyseal lines have fused, but most times it is necessary to correct these deformities when the patients are young, so as to get the bones in a weight bearing alignment When this is done early the abnormal metaphysis takes on the appearance of normal bone after a year or two

OSTEOGENESIS IMPERFECTA

Great confusion exists in the literature

FIG 50 Congenital absence of entire tibia Femur of left leg is a little short (A) Knee is partially flexed and adducted It can be fully flexed but can be extended only a little beyond a right angle There is a dimple in the skin just below knee which is 2 cm in length External malleolus presents a sharp angular appearance at its lower end Foot lacks the support of a medial malleolus so it is turned inward so that medial side of foot rests against medial side of lower leg Foot is in an extreme equinus deformity, and when turned back under fibula is parallel with it (B) X ray shows a fibula a little thicker than normal with dislocation at knee and ankle (C) Patient was fitted with an extension apparatus (D and E) In order to avoid straps over the shoulder to keep brace on advantage was taken of the fact that his knee was fixed near a right angle, and the brace hung on the lower leg to keep it from slipping off He could sit on ring at upper end, and learned to walk nicely without crutches or further support

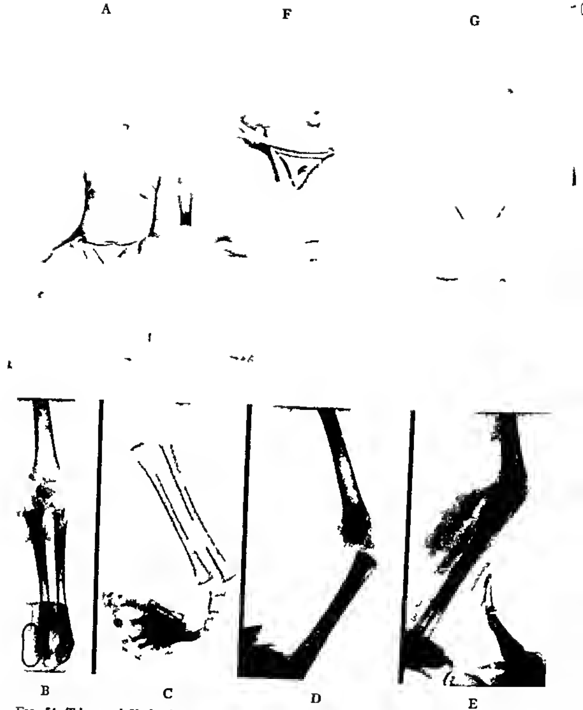

Fig 51 Tibia and fibula the same size congenital dislocation of knees This 15 month-old girl presented several difficult problems for treatment as she had unusual and multiple deformities (A) She had no fingers on either hand and could hold nothing in her hands Both legs were shorter than normal and knees and ankles were dislocated She did not try to pull up and was unable to bear weight when placed on her feet Right knee could be extended only to within 60° of full extension and left to within 45° There was marked crepitus in knees when they were moved and they slipped backward and forward as they were flexed and extended Both bones in lower legs were about same diameter and length (B and C) When knees were extended they slipped forward (D) With slight pressure tibia and fibula could be pushed

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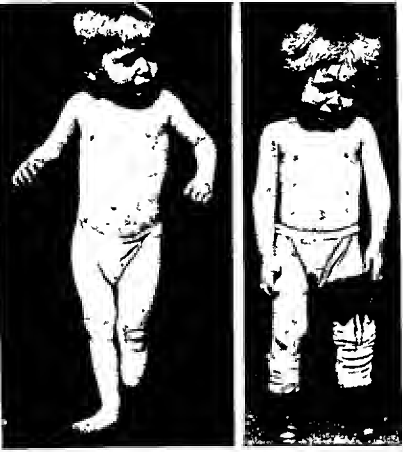


A B

Fig. 52. Congenital amputation of lower leg. Patient was born with a congenital absence of foot and lower part of tibia and fibula on left (A). Also a fusion of the lateral three fingers of left hand. Fingers were separated by operation A simple extension apparatus was first applied to left leg (B) Later an artificial leg was made.

as to the nomenclature of this disease. Hess divided this condition into (a) osteogenesis imperfecta congenita, in which condition the fractures occurred at birth or in early life (these children are either stillborn or survive only a short time), and (b) osteogenesis imperfecta tarda, where the fractures developed between eight and 16. This is the idiopathic osteopsathyrosis which was described by Lobstein in 1833. This condition is also referred to as fragilitas ossium. It has been stated that this is not a good term as there are other conditions which give fragile bones, like bone cysts and metastatic

back under femur (E). There was a congenital absence of both patellae. There was rotation of 180° in each knee joint. Motion was as free laterally as it was in anterior-posterior direction. There was a deep scar over right knee and lateral border of right ankle. Double os calci were present on right (B).

Three fingers were fashioned on each hand by plastic surgery, enabling her to hold toys and feed herself Flexion deformities of knees were corrected by plasters and wedgings. Foot deformities were corrected by plasters and wedgings similar to method used in correction of clubfeet (F). Braces were necessary to control relaxed knees and ankles (G). She first learned to walk holding to parallel bars.

bone tumors Osteopsathyrosis is the term most applicable, as its roots signify "bone and 'crumbling"

Goin[8] says that there are three entities which may be fairly well distinguished one from another (1) Osteogenesis imperfecta, (2) nonhereditary idiopathic osteopsathyrosis and (3) hereditary osteopsathyrosis,

FIG 53 Congenital constrictures of thighs Patient also has bilateral clubfeet, deformities of hands, elbows and shoulders and of hips and knees Grandmother says umbilical cord was wound around legs, which caused constrictions Club foot deformity was corrected by plasters and wedgings Patient died of scarlet fever before treatment was completed

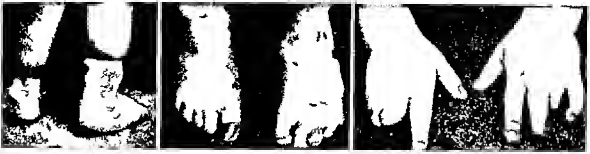
which is the blue sclera and brittle-bone group

Osteogenesis Imperfecta Congenita

While many cases are born with fractures and live only a short while, some of these cases live to adult life Some remain unable to walk and others lead an active life after adolescence, after recovery from many fractures

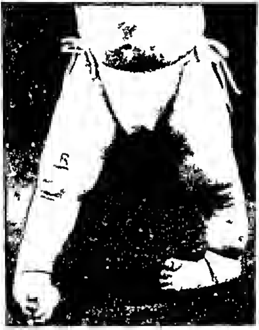
The radiographic appearance in osteogenesis imperfecta varies with the age of the patient and the severity of the disorder Some cases show bones in early life which are broader and shorter than normal, and which lack the molding of normal bones There is a marked osteoporosis of the entire skeleton, with clublike expansion of the extremities of the bones The apparent expansion only appears so because of narrowing of the shafts of the long bones The vertebrae show compression of the bodies, giving them a biconcave shape There may be a marked scoliosis In addition to the deformities from the multiple fractures, the bones show pressure deformities from gravity or weight bearing Toward puberty the shafts of the long bones appear to shrink more while the ends retain their normal size The cortex of the shafts becomes more compact, and the medullary cavity quite narrow The bones which are curved do not show the increased density along the concave side of the curve as is seen in rickets After the patients reach puberty there is less tendency for the bones to fracture For this reason ovarian extract has been given to girls before puberty and these few cases did not have any more fractures Ryam recommends thymus extract by mouth, because his work showed that this increased the amount of callus about fractures, and the few cases who received this did not have any more fractures

Treatment of fractures in these patients is the treatment of fractures in general Even though the structure of these bones is abnormal, they throw out callus rapidly, and when properly treated heal promptly Care should be taken constantly to prevent fractures, and also deformities, as the bones are soft and bend easily, even from gravity Parents tire of taking the child to a doctor so often because of the many fractures and they should be cautioned not to let slight injuries go untreated, as a slight fracture may heal in deformity I have one patient now 15 years old for whom I have reduced 26 fractures at as many different times in



A B C

Fig 54 Congenital constriction of lower leg and toes A 2½ year old boy with congenital constriction above right ankle (A) Left foot was a clubfoot which was partially corrected elsewhere There was contracture of each great toe which could not be caused by umbilical cord with congenital absence of toenail on left (B) Also deformities of both hands (C) Remaining clubfoot deformity on left was corrected and atrophied webbed fingers were separated



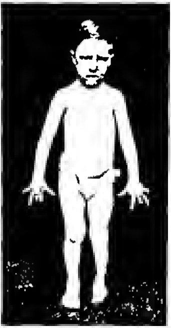
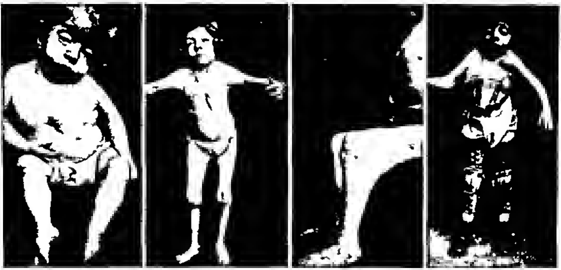


Fig 55 (*Left*) Congenital constriction of lower leg Congenital constriction above left ankle Bilateral clubfeet Congenital amputation of lower third of right forearm Congenital amputation of three fingers left hand Clubfoot deformity was corrected by plasters and wedgings

Fig 56 (*Right*) Congenital constriction of lower leg Born at seven months following injury to mother in streetcar accident Dorsum of left foot is said to have rested against tibia Photograph at five years shows constriction above left ankle He also has constriction of great toe on left, and atrophy of lateral toes Second and third toes show constrictions and fourth and fifth toes are webbed There is a flatfoot deformity on left Fingers show congenital constrictions and amputations



A B C D

FIG 57 Congenital contractures of shoulders fingers hips and knees Patient was one month premature She sat alone at 8 months crawled at 14 months Was first seen at 20 months (A) She had limitation of motion in shoulders hips knees and fingers Also fusion of two long segments of the spine an occult spina bifida and a congenital scoliosis She was slow in her mental development learned to walk with braces at age four She weighed only 25 pounds at 6½ years Knees could be extended only to within 30° of full extension She had a series of plasters and wedgings to get knees in full extension (B) There is a web of skin across axillae from arms to chest and also a web of skin back of knees across popliteal space (C) even though knees now come in full extension A brace was worn to keep knees straight (D) This was attached to a body brace to support the scoliotic spine Brace has a crutch under left axilla to elevate left shoulder She later walked without braces but redeveloped flatfoot deformities which had to be corrected with plasters and a new brace applied

A B C

FIG 58 Congenital band on posterior surface of leg At birth entire right leg was smaller than left and foot was in equinus Patient learned to walk at 16 months She was unable to wear shoes because of equinus deformity (A) There was a tight band extending from ischial tuberosity to heel (B) Right foot could be dorsiflexed only to within 70° of a right angle and knee could be extended only to within 25° of full extension Range of motion could not be increased by force At time of operation Achilles tendon was lengthened by three partial transverse incisions in usual manner but foot could not be dorsiflexed It was found that there was another band of tissue beneath Achilles tendon This was also divided which allowed foot to come up into better dorsiflexion In order to get knee in full extension and to relieve pull this firm tendon like cord was divided at two different levels in the calf and at two in the thigh Foot still could not be brought up to a right angle This was gradually brought up in full dorsiflexion by plasters and wedgings This foot was more difficult to bring up than a resistant clubfoot Deformity of foot and knee were still well corrected when last seen, three years after treatment (C)

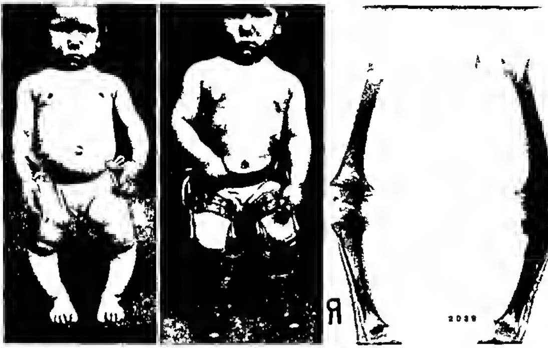
femurs and tibiae and who is now leading an active life

Osteogenesis Imperfecta Tarda

Nonhereditary Idiopathic Osteopsathyrosis Nonhereditary idiopathic osteopsathyrosis is an exceedingly rare condition and because of the confusion of the nomenclature is difficult to separate accurately from the other conditions causing fragile bones It is a disease of infancy and childhood It is characterized by multiple fractures which follow stresses which ordinarily would not produce a fracture

According to Goin the x ray findings are fairly characteristic. The most striking feature is the great disproportion in the size of the epiphysis as compared with the diaphysis of a long bone The diaphysis is slender and usually very irregular The cortex is thin There is a general decrease in the density of the bones and they have a fibrous appearance Usually there are marked deformities and one or more fractures are seen The epiphysis is normal which differentiates this condition from rickets

Hereditary Osteopsathyrosis (Brittle Bones and Blue Sclera) Hereditary osteopsathyrosis includes the cases best known as brittle bones and blue sclera This condition occurs much more frequently than



A B C

Fig 59 Achondroplasia bowleg deformity This patient has always been shorter than normal in stature She walked at one year Bowleg deformity first noticed at age two She was not brought for treatment until she was age five (A) At this time she was 30 inches tall and weighed only 24 pounds She looked like a dwarf and had a marked bowleg deformity X ray showed bones of legs to be shorter and thicker than normal for this age especially in lower legs (C) There is no disturbance of epiphyseal lines but there is a thickening of metaphysis especially just below proximal epiphyseal line of tibia There is not so much increase in density along concave part of curve of tibia as is usually seen in rickets Double bowleg braces (B) were applied with considerable improvement when seen ten months later Final result unknown

the last two mentioned, and was first described by Spurway[7] in 1894 Key[8] made a very careful study of these cases and called sium hereditary deafness, and hypermotility of the joints All of the abnormalities seem to be due to defects in the development of some

FIG 60 Chondrodystrophia foetalis This 3½ year-old boy was two months premature He did not walk until aged 19 months Walked with a waddle when first seen at age 3½ years Shortly after birth it was noticed that left knee could not be straightened and that it was in a bowlegged position He wore braces for a while without improvement

Left femur was 2 cm shorter than right X ray shows a disturbance of normal ossification at many epiphyseal lines There is a wide epiphyseal line in right hip (A) Almost no neck present, and metaphyseal bone is irregular As result of pressure from weight bearing a coxa vara deformity has developed Left hip shows a punched-out area in metaphysis of the neck (The mother s blood Wassermann was negative) Lower end of right femur is normal (B), but there is an increased density of metaphysis of upper end of tibia with an absorption of lime salts on medial side As a result of this a bowleg deformity is present Deformity at lower end of left femur is condition which brought child for treatment (C) Parents thought doctor might have fractured this leg at time of delivery, but the history does not suggest this Femoral condyle is displaced from under tibia and is medial to weight bearing line There is also an area of increased density proximal to epiphyseal line

A cuneiform osteotomy was done proximal to epiphyseal line at lower end of left femur, and condyle replaced directly under femur, restoring normal alignment Bone healed in usual time, giving a nice correction of deformity Slight bowleg deformity on right was corrected with plasters and wedgings

them 'hereditary hypoplasia of the mesenchyme' He says

The most prominent feature of the condition is that the sclerae of the affected persons appear to be china blue in color and that the blue sclerae are transmitted as a dominant hereditary characteristic Many of the affected persons are afflicted with fragilitas ossium of the tissues which arise from the mesenchyme

He does not consider a patient as belonging to this group unless there is another case in the family The affected persons are smaller in stature. Several of my cases showed a premature fusion of the epiphyseal lines

Key states that "all authorities are agreed that the blue of the sclera is not due to a pigmentation but is the result of an abnormal transparency of the sclerotic coat of the eye, which permits the blue uvea to shine through" The color varies with different members of the same family

A very high percentage of these cases become deaf in adult life. The deafness is of the otosclerotic type

Seventy per cent of the cases with blue sclera have had fractures Again quoting Key:

> In contrast to osteogenesis imperfecta the fractures are not as a rule present at birth and are not spontaneous In most cases they occur in early childhood and are always assignable to a definite cause, though the causative force is often less than would be necessary to break a normal bone

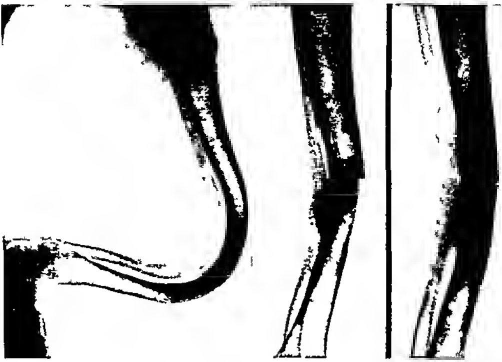
The fractures occur from time to time during childhood, and usually cease about puberty They are usually simple transverse oblique, and often without displacement The shafts are weaker than the epiphysis, so the epiphyses are seldom fractured Key mentions that the pain is slight in these fractures, but many of my patients have complained of about as much pain as the average fracture case Where there is no displacement and no stripping of the periosteum, the fracture heals with a minimum amount of callus

The fibrous structures supporting the joints are unusually loose, and the range of motion is greater than normal. Some families show this more than others A few cases show a tendency to dislocation of the joints.

X-ray of the bones show a marked decrease in density of the bones The shafts are slender and the structure coarsened The tibiae frequently show a marked anterior bowing, with a flat ribbonlike shaft The cortex is thin. There is not the marked change from normal which we see in the groups mentioned above. The bones show the evidence of old fractures, and some-

FIG 61 Osteopsathyrosis blue sclerae and brittle bones Nothing abnormal noticed about this baby until she was three months old, except that she had a slightly enlarged head No one in family with brittle bones At age three months, an alarm clock scared her, causing her to kick suddenly, she fractured left femur—her first fracture Bones at this time show little change from normal During next four years she had 13 fractures of femurs and tibiae Each time fractures were reduced Vitamins and heliotherapy given When plasters were left off it would not be long until she had another fracture, often without any known trauma X ray shows condition at 4½ years She was still being carried on a pillow. When she was four months old her right femur measured 11 5 cm , when she was 4½ years old same femur measured only 13 5 cm Femur had grown only 2 cm during first four years Bones show an apparent expansion of the ends. There is no increase in density along concave side of curved bones since patient is not bearing weight on the bones. All bones in body show decalcification Sclerae are inky blue

According to Key, as quoted above, this patient should have a history of cases in other members of the family to be classified in this group. From every other standpoint the case is typical.



A B C

FIG 62 Blue sclerae and brittle bones Patient did not learn to walk until age two At four she fractured right leg by a slight fall, and less than a year later slipped on a rug and fractured left leg Had a fractured left elbow about this same time Has been unable to walk on crooked legs ever since the fracture, so has crawled on knees until she was first seen at age of 14 Sclerae are a light blue—definitely abnormal, but not so dark a blue as in some cases Blood calcium was 11 7 mg per 100 cc of serum and phosphorus 3 8 mg There is marked anterior bowing of both tibiae, and the bones are flat and ribbonlike Muscles of calves flabby and feet small Lateral x ray of right lower leg shows bowing like the letter "U" (A) There is atrophy of bones with increased density at middle of tibia where curve is most marked Neither tibia nor fibula shows any increased density on concave side of curve as is seen in rickets

At time of operation bones were very hard and brittle It was planned to fashion a mortise and tenon When an attempt was made to cut them they were brittle as china All of the anterior bowing could not be corrected at time of operation After two and a half weeks the plaster was changed, and more correction obtained Union had already occurred to our surprise, so that the bone could be felt and heard to break when force was applied Firm union was obtained in about the usual time following osteotomy of both tibia and fibula Fibula had crossed over under the tibia, and the two bones were so close together that all four fragments fused in a solid mass (B) shows results six months after operation Braces were worn for protection A year after operations, patient tripped and fell and fractured right femur The fragments continued to slip and an open reduction was done Good union Three years after operation, and while still wearing braces, patient tripped and fell and fractured right tibia at point of operation (C) This healed promptly with application of plaster Eight years after operations, and at age 23, she is walking actively and is having no further trouble with her legs

times a premature fusion of the epiphysis

Some cases of fragile bones can be fitted into these classifications, while others are found which are contrary to the differential points given The child shown in Fig 61 has deep blue sclera, and still she best illustrates osteogenesis imperfecta congenita At three months she broke her leg by kicking it suddenly During the first four years of her life I treated 13 fractures for her in both femurs and tibiae There was practically no growth in length in four years, and the bones which were fairly normal looking at three months show the extreme atrophy with all the changes described, at 4½ years

A more typical case is that of a 14 year old girl who had crawled on her knees since the age of five (Fig 62) Her bones showed atrophy, but were more typical of the average case of blue sclera The marked anterior bowing of the tibiae was corrected by osteotomies The bones healed readily after the operation The last fracture was at the age of 17 At her present age of 23, she walks actively and keeps house and works in a cotton mill

I have another family in which two sisters and a brother have had brittle bones without blue sclera They have had multiple fractures I have reduced 26 fractures for one of the girls The brother and one sister have each married, and they each have a child with brittle bones and multiple fractures These cases would meet all the requirements for this classification except the blue sclera These are mentioned to show how difficult it is to fit all cases of brittle bones into the above classifications

MULTIPLE CARTILAGINOUS EXOSTOSES

Ehrenfried[9] described a distinct clinical form of multiple exostosis as "hereditary deforming chondrodysplasia" In addition to the exostoses there is a bending and shortening of the bones and a widening and irregularity of their metaphyseal ends It is congenital and may be traced through several generations It is most often seen between nine and 20, and affects the bones of the forearm and lower leg most often, but also frequently involves the humerus and the femur

This is one of the easiest conditions among bone tumors to diagnose by x ray There are multiple exostoses about the ends of the bones either of the pedicle or broad base type The exostoses point away from the joint in the direction of the muscle pull There is a marked widening of the metaphyseal ends of the bones Often the upper end of the fibula is expanded and fused to the tibia (Fig 63 B)

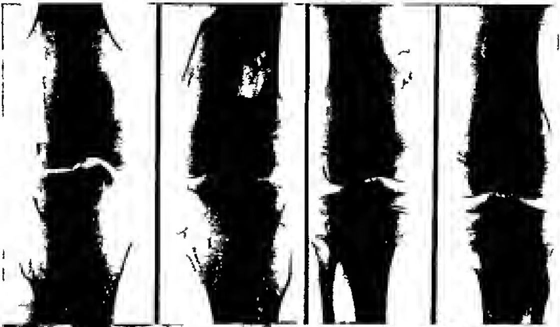
Treatment There is no treatment for hereditary deformity chondrodysplasia except excision of the growth which is causing trouble If the tumor becomes sore and painful or causes injury to nerves or vessels, or interferes with function, it should be removed immediately Occasionally they become malignant and so should be removed if they begin to grow suddenly In removing any exostosis care should be taken to remove all of the periosteum covering the bony mass and also to remove some of the normal cortex with it in order to prevent recurrence The soft parts are dissected away from the tumor and the periosteum cut through on the cortex of the shaft a few millimeters from the base of the exostosis A part of the cortex together with the tumor may be removed with a chisel

A typical case is shown in Fig 63 The father had the same condition with a similar distribution of lesions The exostoses are distributed above and below each knee and about the ankles Only the mass above the right knee on the medial side gave pain, and this was removed Later the one below the right knee became sore and was removed

CONGENITAL COXA VARA

Congenital coxa vara is a rare deformity of the hip, characterized by a progressive lessening of the angle between the neck and

B C D E



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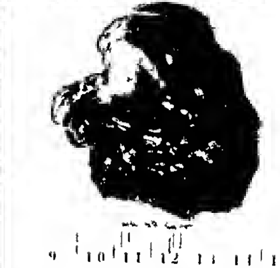

F

Fig 63 Multiple cartilaginous exostoses Exostoses first noticed when patient was between two and three years old He did not have soreness enough in the knots to come for treatment until he was aged 11 (A) He has an exostosis over upper end of each humerus as well as above and below each knee and over lower end of each tibia Also nodules on the ribs Examination of the father (B and C) shows exostosis above and below knees very similar to the son's but not so large X ray of father's right knee shows bony striae going across from expanded head of fibula to tibia showing that these two bones have fused X rays of son's knees (D and E)

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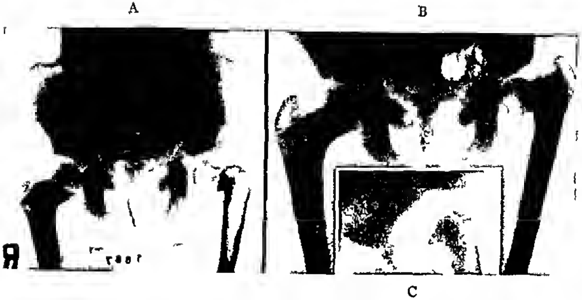

Fig 64 Congenital coxa vara Patient did not begin to limp until aged three At age four (A) there was a definite limp with 1 cm shortening on left X ray shows head and neck at almost a right angle to shaft, with a vertical epiphyseal line instead of the more nearly transverse epiphyseal line Center of ossification for greater trochanter beginning to present more of a beaklike appearance

Six years later (B) she had more limp and left hip was in an adducted position which could not be corrected Left leg was 1 5 cm shorter than right by actual measurement but was apparently 5 5 cm shorter due to adduction Angle between neck and the shaft had decreased to 57° Greater trochanter was more prominent Atrophy of head still present Ischium and pubis at symphysis show a congenital lack of development There is also a congenital absence of most of each clavicle and some abnormalities of spine

Because of apparent shortening on left and inability to abduct a subtrochanteric osteotomy was done, and a Hoke plaster traction apparatus applied with plaster on well leg and traction on left by means of adhesive Position of hip shown one month after operation is satisfactory (C) Operation done at age ten At age 14 she has practically full range of motion in left hip She walked on toes of left foot before operation but four years after operation she places left foot flat on floor and is free from discomfort

the shaft of the femur A careful study of this condition has been made by Zadek[10] Frequently it is not noticed during the first two or three years of life The child then develops a painless limp, which becomes painful by adolescence Should the neck give away and nonunion develop, the disability becomes marked Examination in addition to the limp shows an elevation of the greater trochanter a shortening of the leg due to the adduction deformity, and a limitation of motion in abduction There is a positive Trendelenburg sign The head of the femur can be felt in the groin This condition might easily be mistaken for congenital dislocation of the hip It has also been mistaken for a fracture of the hip Occasionally there are other congenital de

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show, in addition to exostosis, the same widening of the metaphyses of tibia and fibula and femur This is very evident when metaphyseal region is compared with shafts only a small part of which show in these x rays Exostosis on medial side of right femur was removed (F) This shows the numerous cartilaginous outgrowths It is still covered with smooth glistening periosteum At base can be seen normal cortical bone, which was removed along with tumor

[It is wise to remove apparently normal cortical bone beneath bases of all osteomata and exostoses in order to eliminate risk of recurrence —Ed]

formities The coxa vara becomes more marked from weight bearing (Fig 64 A and B)

The x ray of the hip suggests a loss of substance as in a fracture It also shows the diminution in the angle between the neck and the shaft of the femur In the case illustrated the angle changed from a right angle at the age of four to an angle of 57° at ten The epiphyseal line is vertical instead of the more nearly transverse line shown normally At times it may branch like an inverted Y enclosing bone between the two arms A coxa vara is shown in Fig 60 where the epiphyseal line is very wide but this is not the typical finding in this condition Another case of coxa vara is shown in Fig 42 The trochanter is elevated and has a beaked appearance There is a slight actual shortening of the affected leg but a marked apparent shortening due to the adduction of the affected hip These patients walk on the toes of the affected leg to compensate for the shortening

It is difficult to restore the hip to normal function but it can be greatly improved by operation Zadek suggests drilling multiple holes in the neck of the femur to improve the blood supply and to stimulate ossification A subtrochanteric osteotomy is done to correct the angle of the neck Sorrell[11] removes a wedge shaped section of bone from the lateral side of the shaft in doing this osteotomy and inserts the fragment of bone reversed so that the base of the wedge is on the medial side of the shaft

In doing a subtrochanteric osteotomy in an ankylosed hip it is easy to control the position of the fragments because the short proximal fragment is fixed and the length of the leg gives good control of the distal fragment When an osteotomy is done on a movable hip as in congenital coxa vara it is difficult to control the proximal fragment It has been my experience in treating these cases that the head and neck will rotate and that the adduction deformity cannot be well corrected I have used a Hoke well leg traction apparatus after operation with plaster on the well leg and with the metal traction apparatus placed in abduction and have made gentle traction on the leg by means of adhesive In this way we were able to prevent shortening and were able to maintain the abduction with satisfactory results (Fig 64 C)

CONGENITAL DEFORMITIES OF KNEE

Congenital Dislocation of Knee

The tibia is practically always displaced anteriorly and there is often an associated genu recurvatum Fig 51 D and E show the x rays of a dislocated knee showing the bones of the lower leg displaced forward when at rest with a little pressure the bones of the lower leg can be made to slip back under the femur The photograph of this same patient after correction shows a dimple over the knee which suggests some congenital abnormality about the knee The range of motion in these knees was limited so that the right could be extended only to within 60° of full extension and the left to within 45° There was marked crepitus when the knees were moved Each lower leg could be rotated under the femur about 180° Also there was free lateral motion in the knees The flexion deformity was corrected by plaster and wedgings

In correcting flexion deformity of the knee a long cast should be applied extending from the toes to the upper thigh A few days later the cast is cut about three-fourths of the way around at the knee leaving a hinge of plaster anteriorly Wooden blocks are inserted between the edges of the cast posteriorly After the block is inserted a plaster bandage is applied to hold it in place A progressively larger block is inserted once or twice a week When the deformity has been corrected a brace should be worn to hold the knees straight (Fig 51 G) After full growth has been obtained a knee fusion may be indicated

Congenital Genu Recurvatum

This is a rare deformity, in which the quadriceps muscles and tendon are shortened This should be treated by plaster and wedgings as described in the paragraph above, only here the blocks are inserted anteriorly on the concave side of the curve When seen in older children a plastic operation on the quadriceps tendon is also indicated

Congenital Dislocation of Patella

A congenital absence, or a congenital dislocation of the patella should not be diagnosed by x ray until the child is four years old as the center of ossification for the patella does not appear until the beginning of the third year However, the cartilage for the patella can be felt at birth, and the position of the patella ascertained

A recurrent or habitual dislocation is different from a congenital dislocation In recurrent dislocation, the patella was in the normal position at one time and later became dislocated It may have been dislocated by injury, after which it redislocates easily It is thought in recurrent dislocation that there might have been a predisposition to dislocation as the result of a congenital laxity of the joint or an abnormal anatomic contour of the knee as a flattening of the lateral condyle or a knock knee A true congenital dislocation is frequently associated with a major deformity (Figs 43 and 45) It is rare to find a patella dislocated as shown in Fig 65 If there is an associated flexion deformity of the knee, this should be corrected and if the quadriceps muscle is absent as in this patient a brace will have to be worn to stabilize the knee This patient later developed an osteoarthritis in the knee with so much pain that a knee fusion may well be indicated Where the quadriceps tendon is active any of the operations used for the recurrent dislocations of the patella may be used for congenital dislocation [See Chapters 15 and 37 for procedure —Ed]

Congenital Synostosis of Knee

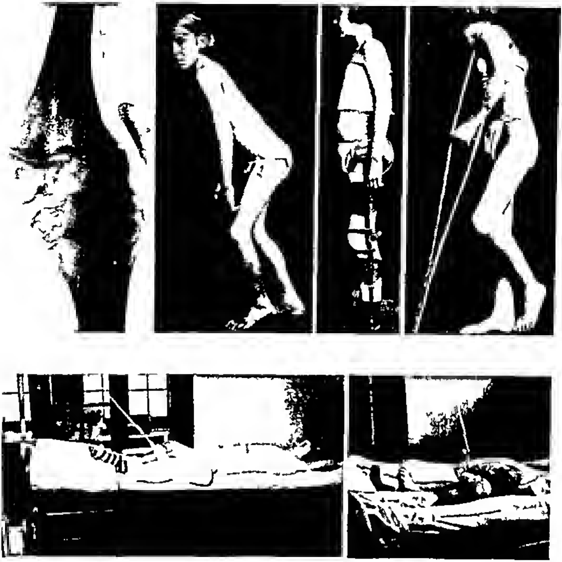
This condition is usually associated with a major deformity of the leg frequently with a congenital absence of a part of one of the long bones (Fig 43) In this patient the epiphysis of the femur and tibia fused giving the appearance of a patella between the bones In order that she might wear an artificial appliance the flexion deformity in this case was corrected by a cuneiform osteotomy through the knee care being taken not to injure the epiphyseal line Another patient with congenital synostosis of the knee also shows a congenital absence of the fibula (Fig 45) There is a fusion of the epiphysis of the femur and tibia and an absence of the patella He was able to wear an extension apparatus without need for an operation to correct the slight flexion deformity of the knee

CONGENITAL PSEUDARTHROSIS OF TIBIA AND FIBULA

The pathology of congenital pseudarthrosis of the tibia and fibula is not known but it is evidently due to a congenital abnormality of the structure of the bones involved A congenital pseudarthrosis is entirely different from a fracture seen in normal bones at birth or later In normal bones especially in children where there is a fracture, there is an abundant formation of callus with rapid healing This is always true in birth fractures in the humerus and femur In these congenital pseudarthrosis cases there is no callus laid down and non union persists The fracture is usually at the junction of the middle and lower third of the tibia, or just above it

Many times we do not see these cases until after the fracture has occurred In my series of ten cases I have been fortunate enough to have observed some of these bones before the fracture has occurred In these cases the bone is definitely abnormal, and closely resembles the bowed tibia mentioned above under abnormalities of the tibia (Fig 48) There is an anterior bowing

B A C D

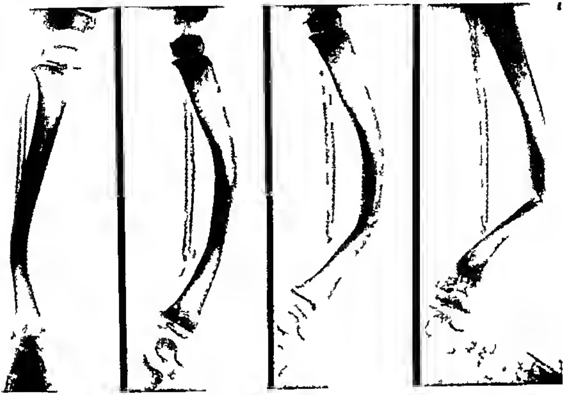


E F

FIG 65 Congenital dislocation of patella with absence of quadriceps Patient was born with left knee flexed When she was aged 1½ years she was given an anesthetic elsewhere left knee was forcibly straightened and plaster was applied for six weeks Deformity gradually recurred When first seen at age 11, she walked with a bad limp with left knee flexed (A) Knee could be forcibly extended only to within 40° of full extension Patella could be felt lying over lateral condyle of femur and just above head of fibula (B) There was no quadriceps tendon going over anterior surface of knee She had complete loss of power in extension of knee

Deformity was corrected by plasters and wedgings and a brace applied to hold knee in extension (C) After a while she discontinued brace and knee became flexed and very painful, and tibia was found to be dislocated posteriorly under femur (D) In order to correct posterior dislocation and flexion deformity of knee, a Kirschner wire was inserted in upper end of tibia and by overhead traction tibia was pulled forward and dislocation

(Continued on next page)



A B C D

FIG 66 Congenital pseudarthrosis of fibula with sclerosis and bowing of tibia At birth right lower leg was bowed anteriorly and laterally When seen at age 16 months she had not learned to walk She had had no known fractures at this time An anterior posterior x ray (A) shows ununited fracture of fibula just below junction of middle and lower thirds Tibia shows an increased density of middle third with lateral bowing There is no evidence of a crack or cyst in tibia Lateral view (B) shows that more bone is deposited on concave side of curve Parents were told that this tibia would fracture a brace was made to immobilize and protect tibia Three months later, while wearing brace patient slipped as she was climbing around a rocking chair hurting her right leg Three weeks after the fall she was brought for examination There was false motion in tibia (C) Plasters were worn for five months in order to see if good external fixation would induce healing but the bones gradually tapered down to points showing increased sclerosis and no callus formation (D) There were multiple transverse lines in lower fragment and an area of increased density and angulation about 2 cm from lower end, suggesting presence of a greenstick fracture at this point This was found to be a complete transverse fracture with nonunion at time of operation A long onlay bone graft was placed across both fractures and held in place with vitallium screws This has been applied too recently to report final result

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and flexion deformity was corrected (E) Pull at first was downward until posterior dislocation was corrected, and then more nearly vertical until tibia was brought forward in front of condyles of femur Sandbags were placed about foot to control rotation and another on top of knee for counterpressure (F) As long as patient was in traction she was free from pain After deformity had been corrected a straight leg plaster was applied to hold correction and within a day she began to complain of pain in knee as before After removal of cast, brace was again applied Because of the arthritis a knee fusion may be indicated later

and sometimes an associated lateral bowing The involved leg is always shorter than the normal leg The bone is more dense throughout the middle third There is increased condensation on the concave side of the curve (Fig 66) Often the shaft presents several cystlike cavities which may be the site of a fracture later The fibula is usually smaller than normal and shows absorption of bone salts It may be that the shearing force placed on the fibula, because of the angulation of the tibia causes abnormal pressure and absorption This absorption of lime salts is seen best in the fibula and the lower end of the tibia

The fibula usually fractures first, throwing more strain on the tibia and later the tibia will fracture either spontaneously or from a very slight trauma Before the fracture, the tendo achillis is contracted, and the foot is in equinus After the fracture there is more shortening of the lower leg because of the anterior angulation, and the foot may come up in extreme dorsiflexion The angulation is always forward and lateral The proximal end of the lower fragment usually becomes pointed and the distal end of the upper fragment becomes cup-shaped, and a false joint is formed After a little while the ends of the fragments become sclerosed and the medullary cavity obliterated The entire bone shows more atrophy The lower fragment often shows multiple transverse lines throughout most of its length (Fig 66 D) In this case there occurred a transverse fracture which was present on removal of the plaster, which was not present in the x ray made before its application This is an unusual finding The gap between the fragments at the junction of the middle and lower third becomes larger and the extremity becomes shorter At times fibrous tissue is found between the fragments, and at times clear straw colored fluid, like synovial fluid is found in a small cavity This is the false joint which justifies the name "pseudarthrosis"

Treatment Most authors state that attempts to bridge this gap by bone grafts in children have failed Putti reported 11 failures in 13 cases Henderson reported three failures in five cases it was he who first called attention to the fact that prognosis was better in older patients, and recommended that the operation be postponed until after puberty In the meantime the patient should walk on a caliper splint Even if this is done, the bones grow very little and the fragments become more pointed, the space between them greater, and the angulation more marked It is my belief that a bone graft operation should be done at an early age Nonunion following a bone grafting operation is probably due not so much to the youth of the patient as it is to inadequate fixation, both internal and external In the small child the bones are so small that grafts cannot be cut with the twin saws and driven in place according to the methods used for adults It is also difficult to apply secure external fixation

Better bone can be obtained for a graft by getting it from the opposite leg, but the parents are often reluctant to give their consent to the use of the bone from the good leg and at times the surgeon feels that if the bone can be obtained from the same leg it is desirable not to disturb the normal leg especially in cases where the child is quite small

One of the essentials in doing a bone-graft operation in these cases is the proper preparation of the fragments before the graft is inserted The sclerosed ends of the bones should be removed so as to allow fresh bone ends to come in contact No more bone than is absolutely necessary should be removed The cortex on one face of the bone should be removed, so as to open up the medullary canal Often the bone is so brittle that any sculpture of the bone is difficult because of risk of breaking the bone This accident may be avoided by first drilling a row of small holes through the anterior cortex. By joining these with a sharp chisel a groove is made in the bone

Sometimes there is enough bone present to do a step cut procedure

I have tried all types of bone grafts in these cases, except the intramedullary peg I used a diamond shaped inlay graft successfully in a seven year old boy with congenital pseudarthrosis in 1928 This method has been described by Gallie [12] One of the chief objections to this graft is that it is difficult to split the brittle fragments to receive the graft, without one of the fragments breaking When the diamond shaped graft is successfully inserted, the elasticity of the fragments holds the graft in place and maintains good bone contact The graft restores the bone to almost its normal thickness at the point of the pseudarthrosis

The fragments are usually so small that if an inlay graft is used, this graft has to be so small that it offers very little strength The graft most commonly used has been the onlay graft When only one graft is used, this should be placed on the lateral side of the tibia, next to the fibula, where the graft will be buried beneath muscles, which will furnish it with a better circulation At present, in the older children, a graft is placed on each side of the tibia and vitallium screws are inserted through one graft, the tibia, and the other graft This gives the best possible internal fixation If the child is too small for bone screws, an onlay graft can be used by making a rather deep cut into the cortex of the bone at each end of the graft, raising up a flap of the tibia without breaking it The graft is then slipped under each flap from the side The elasticity of these fragments will hold the graft firmly in place This type of graft has given a fairly high percentage of takes (Fig 67 C) This works best for a thin, flat graft, but if a massive bone graft is used, larger openings can be made (Fig 67 G) Small fragments of bone should be placed about the point of fracture, and packed in any space about the ends of the tibia All crevices should be packed with fragments of spongy bone from the medullary canal where the graft was obtained These fragments carry with them the endosteum which is in the mind of many probably the best source for the reproduction of new bone

In the patients in my ser[illegible]n union did not take place ther[illegible] inadequate external fixation The pl[illegible] extended only from the toes to the [illegible]p thigh In a small child this doe[illegible]t sufficient fixation, and unless the knee flexed it does not prevent torsion strain I[illegible] all cases after operation, the plaster [illegible]h[illegible]ul[illegible] be in the shape of a spica including th[illegible] pelvis The hip and knee should be slightly flexed

I have felt that the external fixation is so important that I treated one early patient by external fixation alone, and after a year obtained solid union both clinically and by x ray (Fig 68) This patient refractured his tibia and union was again obtained by external fixation alone When he refractured his tibia the third time, external fixation failed to secure union

After union has been obtained it is very important that a snug fitting brace be worn to prevent fracture These braces should be made over a plaster model of the leg The leather is shrunk over the anterior surface of the model, and made to lace up in the back of the leg (Fig 69) The brace is attached to a foot plate under the foot, and the shoe slipped on over the foot and foot plate No motion should be allowed in the knee I have had several cases refracture the leg when motion was allowed at the knee

It is a question what to do for the patient who is seen with the bowed leg before it has fractured On several occasions I have gradually corrected the angulation by a series of plasters and wedgings, and then applied a brace Care should be exercised not to fracture the bone If weight bearing is permitted on a curved leg, most of these bones will fracture sooner or later

Operative correction of these curved

A B C D

E F G H I

FIG 67. For legend see p 61.

tibiae should be undertaken with the full knowledge of the risk of nonunion, and adequate fixation should be maintained for a long time My first experience with this condition was the after treatment of a patient who had had a double transverse osteotomy done by a general surgeon who did not realize the type of bone on which he was operating (Fig 70) Two bone grafts were necessary before union was obtained Sixteen months later she fell and refractured the leg and a third bone graft was inserted, which finally gave a good result (Fig 70 D) When an operation is necessary on one of these abnormal bones, a long oblique osteotomy should be done (Fig 48 C) This will give the maximum amount of raw bone surface for the production of callus, and will also give a better correction and a firmer union

Finally, if union cannot be obtained after several attempts by bone grafts, and the space between the fragments has increased, each fragment of the tibia can be grafted to the fibula I have obtained a weight bearing leg in one case by this method after three failures at bone grafting The fibula has hypertrophied between the fragments giving a bone almost as large in diameter as a normal tibia

I have never done an amputation for a congenital pseudarthrosis but when we consider the enormous cost of the long hospitalization required for one or more operations and the cost of braces needed for protection during most of the growing period and the possibility of additional fractures with the necessity for additional bone graft operations, it seems that the wisest procedure in some cases, at least might be an amputation and an artificial leg

[While, from an economic standpoint this latter view is unquestionably sound it is very difficult to convince parents of these young children to take that viewpoint — Ed]

Fig 67 Congenital pseudarthrosis of tibia and fibula Left tibia of a 14 month-old boy (A) whose left leg was first noticed to be a little crooked at age three weeks Deformity was barely perceptible at that time but leg gradually became more crooked Bones show marked atrophy with anterior bowing of both tibia and fibula but with no break in continuity of either Tibia shows a cystlike cavity, and increased density along concave side of curve

Parents were urged to get a brace to protect this leg They were told that it would probably fracture even with a brace They got the brace, but did not apply it Four months later while father was playing with child on bed, left lower leg bent and fractured It was three months before child was brought for examination (B), and at that time he had as free motion in middle of leg as he had in his ankle

Parents would not consent to operation until nearly four years later He was then six years old Pointed end of lower fragment was laid in a mortise cut in upper fragment Then an onlay bone graft was obtained from upper tibia This was placed across mortise by driving a chisel into the cortex of each fragment above and below, and turning up a centimeter or more of bone and by slipping this onlay graft under each piece of elevated bone (C and D) Elasticity of these fragments held graft in place and gave good fixation Fragments were too small to permit use of bone pegs

A year and a half later there was good union (E), and patient was permitted to walk, wearing a brace Two years after bone graft operation, patient fell at school while wearing brace, and refractured this leg His parents waited six weeks before bringing him back, he again had considerable false motion at point of fracture Plasters were worn for two months in the hope that this fracture might unite like an ordinary fracture A definite pseudarthrosis developed with no callus formation (F) A massive bone graft was then taken from opposite right tibia and inserted into each fragment of left tibia as described above, forming an onlay graft across point of fracture (G and H) Many thin shavings were placed about the area of fracture, and also about the atrophied fibula Wound healed nicely and graft gave a good union as shown in x ray made three years later (I) It is now four years since second bone-graft operation Patient has good union and is walking nicely, but is still wearing a brace for protection and a cork lift under shoe to compensate for 6 cm shortening

FIG 68 Congenital pseudarthrosis of tibia and fibula At birth right lower leg was crooked and right foot was turned up so that it rested upon lateral side of knee Family physician applied a wooden splint Patient was seen first when aged five weeks (A) There was a cystic degeneration of lower half of both tibia and fibula with pathologic fracture, and condensation of lime salts along edges of cyst Baby was treated for a year by plasters to see if good external fixation might induce union This was successful and at age 14 months a brace was applied to protect the bone and patient allowed to walk

By the time he was aged 2½ years he had a tibia of about normal size, but not of normal structure (B) There was anterior bowing with condensation of middle third, and some areas of lessened density Three months after this x ray it was noticed that patient was limping and having some pain in leg It was thought that he had outgrown his brace so a new brace was made Two months later without any known injury, x ray showed a pathologic fracture at point of a cyst in lower end of tibia After three months of plasters there was no healing of fracture (C) Plasters were continued however being changed about every two months Nine months later union had again taken place (D), and braces were again applied A pseudarthrosis again developed and two years after last x ray shown at age of 5½ years an operation was done and two onlay grafts obtained from upper tibia were laid across line of fracture Wound healed per primam After a year and a half of immobilization union had not taken place so a second bone graft operation was done taking bone from the opposite left tibia and putting it in the right Now at age ten, and two and one-half years after last operation, union does not seem to be strong enough to try a brace He is wearing a long leg cast with a walking iron incorporated

CONGENITAL DEFORMITIES OF FOOT

Following Spina Bifida

Spina bifida "occulta" is often found accompanying clubfoot deformity, but is of little clinical importance The more marked deformities of the feet follow ' spina bifida vera " The treatment of the tumor on the back is in the province of the neurosurgeon The associated deformities of the lower extremity should be treated by the orthopedic surgeon Most of these patients have some control of the lower extremities but some have a flaccid paralysis and others a spastic paralysis It is this muscle imbalance which produces the deformities There is nearly always a partial or complete *loss of* sphincter control, which prevents these children from being permitted to go to school There may be a partial or complete loss of sensation

A test should always be made for sensation before beginning *treatment If the* foot is anesthetic, it is very difficult to apply and wedge plaster without producing pressure sores In fact, normal weight bearing points will develop sores This is particularly true in deformed feet where the pressure is not distributed evenly over the foot These pressure sores are known as *trophic ulcer*

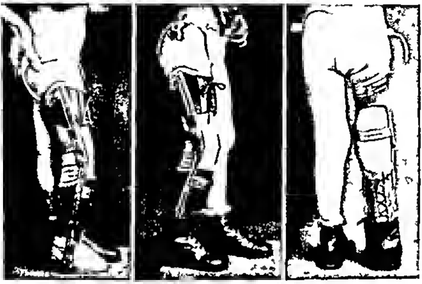

FIG 69 Brace worn to protect tibia from fracture This brace was worn for two years by patient in Fig 68 Leather over anterior surface of lower leg was *molded over* a plaster *model of the leg,* and is made to lace in back Brace is attached to a metal footplate and shoe slipped on over foot and brace It was felt that this gives better protection to, and can be applied with less strain on the leg This particular brace has a *movable joint* at knee I have had several *patients fracture* tibia *while wearing such a brace* and so have discontinued motion at knee

They are deep punched out ulcers with elevated, hard edges The ulcers usually have a very foul odor and are difficult to heal

Treatment should begin with the trophic ulcers if they are present (Fig 71) *It is* necessary to put the patient to bed to prevent weight bearing *The ulcers will not* heal while the patient is bearing weight on them Wet dressings with a mild antiseptic are kept on the ulcers constantly, changing these once or twice a day After the infection is lessened and the hard surrounding

A B C D

Fig 70 Congenital pseudarthrosis of fibula with bowing of tibia This six year-old girl had a crooked left leg from birth There is an ununited fracture of lower end of fibula with marked sclerosis of middle third of tibia (A), with anterior and lateral bowing (Sclerosis is more marked than is shown in x ray, as middle portion was given less exposure when print was made so as to show detail Lower end of fibula was retouched for better demonstration)

An osteotomy at two levels was done by a general surgeon to correct deformity Wound healed without infection but bone laid down no callus Middle fragment lost its circulation, and became dense like a sequestrum X ray made through plaster shows condition 19 days after operation (B) Snug fitting plasters were worn for five months, being changed infrequently Weight was borne on leg part of this time X ray still showed no evidence of new bone formation Middle segment was being absorbed Ends of the two main fragments became more dense near ends, as shown in x ray made 131 days after operation (C)

A bone graft was done from upper tibia Wound healed per primam but bone union did not occur Six months later a massive bone graft was taken from opposite tibia and firm union was obtained After four months she was allowed to go without further fixation A week later she refractured opposite tibia from which graft was taken, while getting up from a sitting position This healed in the usual time with fixation in plasters Sixteen months after successful bone graft on left she fell off bed and refractured left tibia through grafted area After four months in plaster she still had nonunion, so a third bone graft was inserted This was a massive bone graft from right tibia This again gave solid union Result three years after this third operation is shown in (D)

skin is softened, the ulcer can be made to heal more rapidly if the patient is given an anesthetic, when necessary, and the surrounding skin trimmed down to normal bleeding tissue on all sides, removing the ulcer as one removes the core of an apple As soon as the ulcer is healed the foot deformity should be corrected This is usually a clubfoot or a flatfoot deformity These are corrected by a series of plasters and wedgings as described below If care is taken to correct these feet slowly, it can be done without getting pressure sores The deformity should be well overcorrected The weight will then be distributed over the foot in the normal manner, and no more ulcers will develop The deformity has a great tendency to recur after treatment has been discontinued because the muscle imbalance is still present For this reason these patients often return for a second or third course of treatments At times braces are indicated, depending upon the amount of paralysis present

Congenital Flatfoot

Congenital flatfoot as used here does not refer to that mild form of flatfoot seen in many babies who have no well defined arch to their foot, but refers to that marked type of deformity seen at birth in which the feet assume a calcaneovalgus position like a reversed clubfoot It is a true pes planus with a prominence under the middle of the foot Often the feet are abducted so much that the toes of each foot point outward each 90° away from the midline This condition is congenital, and can sometimes be traced back through several generations At times it appears in a family with a strong tendency toward clubfeet (Fig 72), and occasionally we see a patient with a congenital flatfoot on one side and a congenital clubfoot on the other side (Fig 73)

It is not necessary to go into a minute description of the condition, as it is somewhat similar to the familiar acquired flatfoot In congenital flatfoot the midline of the astragalus points medially toward the midline of the body at an angle of about 45°, as shown in the anterior posterior x ray (Fig 72 B) In the lateral view it points almost straight down toward the sole (Fig 72 C) The scaphoid is lateral to the head of the astragalus in the anterior posterior view while in the lateral x ray it is not in front of the head but is displaced upward and is on the superior surface of the neck

Treatment of this condition is much easier if it can be begun when the patient is young and the final result gives feet which are more nearly normal (Fig 73 D and E) In congenital flatfeet the deformity can be corrected by a series of plasters and wedgings In applying the plaster the great toe is turned downward and the entire forefoot is adducted so as to restore a longitudinal arch by the combination of the two movements It is held in this position while the plaster hardens In a few days a wedge of plaster, with the base on the medial side and about the level of the midtarsal joint is removed from the foot The forefoot is turned down and inward a little more and the plaster closed After two or three wedgings a new plaster is applied The foot is thus gradually corrected in the same manner a clubfoot is corrected except that the forefoot is carried in the opposite direction When the forefoot is adducted enough for the arch to be restored and enough for it to remain in the corrected position when released, it may be ready to be brought up in dorsiflexion to stretch the tendo achillis, which is frequently contracted Before bringing the foot up an anterior posterior x ray should show the midline of the astragalus pointing toward the great toe and the formerly dislocated scaphoid in front of the head of the astragalus If the valgus deformity is found not to be corrected, plasters and wedgings should be continued until this has been accomplished Then the foot should be wedged in dorsiflexion, keeping the forefoot turned inward This is accomplished in the manner as described below for clubfeet.

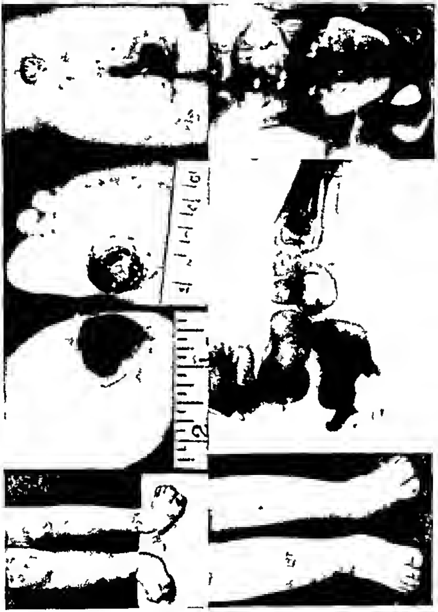

Fig 71 For legend see p 67

In older children it may be necessary to forcibly manipulate the feet under an anesthetic if they cannot be corrected otherwise, and it may be necessary to lengthen the tendo achillis by one of the plastic operations

In still older patients, any of the many operations recommended for acquired flat feet may be used My preference in these older patients, who cannot be corrected by the *nonoperative method, is to do the* operation recommended by Hoke[13] for flatfeet If the position of the astragalus cannot be corrected, I do a triple arthrodesis as devised by Hoke[14] for paralytic flatfeet These operations on the bones should be postponed as long as possible, and should not be done under the age of ten if it is at all possible to get a fair correction by some other method A much more flexible and more nearly normal foot can be obtained if the deformity can be corrected without the use of surgery (Fig 73 D, E, and F)

Congenital Metatarsus Varus

At the first glance this condition might be confused with congenital clubfoot deformity It might be thought of as a "third of a clubfoot," because it presents forefoot adduction A more careful examination of the foot, however, shows that it is quite different from a clubfoot, and that it presents a very definite clinical entity Instead of having a varus heel, there is always a valgus heel A very accurate description of this condition has been given by Peabody[15] He says (see Fig 40)

Classification of our deformity with common clubfoot seems quite improper from a number of striking factors in the pathology In the first place, equinus is never present in any degree In the second the sole of the foot is always flat, or nearly so Thirdly, in spite of a first impression of a varus foot, there is seen to be no ankle varus or supination at the subastragaloid joint, but, on the contrary valgus or pronation, with marked inward rotation and luxation of the head of the astragalus, the scaphoid and mesial cuneiform being displaced laterally The cuneiform bones are rotated in a varus direction and overlapping so that the upright perpendicular might pass through all three of these bones More striking is the deformity of the metatarsals To a slight degree the fifth and to a marked degree the fourth, third, and second metatarsals are incurved in their diaphyses

Fig 71 Spina bifida vera flatfeet and trophic ulcers

At birth there was a swelling and ulcer at lower end of spine which drained for a month and healed His feet were flat He did not sit alone until aged one Walked at age two Has never gained sphincter control Pictures in this series were made at age nine (A) For past 17 months he has had a trophic ulcer on right heel, and for 8 months another under head of first metatarsal on left, which have resisted all home remedies He walked with knees flexed and feet abducted about 60° in a very bad flatfoot position There is a large punched-out ulcer under right heel, with thick skin which is peeling off around ulcer (B) An instrument can be passed down to the bone, and x ray shows a punched out osteomyelitic area in os calcis (C) He has another punched out ulcer over head of first metatarsal on left (D) The feet are in such marked flatfoot position that lateral border is elevated, and weight is borne on medial border of foot (A) There is a hard cornlike area of skin surrounding this ulcer On his back can be seen the original spina bifida mass, which is 3 x 4 cm (E) Surrounding skin is puckered and consists of scar tissue Around the edges of this is an area covered with long hairs He has another deep ulcerated area over sacrum extending forward to anus, it has been present for ten months and has elevated, overhanging edges With loss of sphincter control it has been difficult to get this ulcer to heal Palpation of back shows an absence of spinous processes from third lumbar downward Failure of neural arches to form is shown in (F)

The three trophic ulcers were treated with wet boric dressings Ulcers over sacrum and on left foot healed rather promptly Ulcer over right heel did not heal until osteomyelitis of os calcis was curetted Flatfoot deformity was then corrected by a series of plasters with wedgings, and, after feet were well corrected, swung in shoes were applied This shifted weight from previous points of pressure, and distributed it evenly over the normal weight bearing areas Three months after admission patient was dismissed with all sores healed and flatfoot deformity corrected (G)

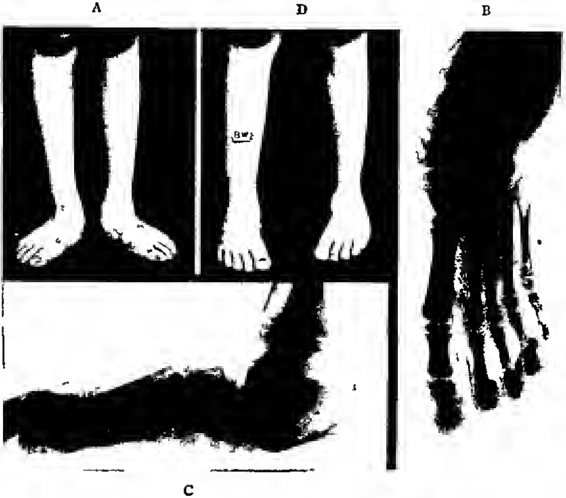

FIG 72 Congenital flatfeet Feet in this patient present usual deformity seen in acquired flatfeet only deformity is more marked (Patient's sister shown in Fig 73) Heels turn out in valgus longitudinal arch is obliterated and there is marked bulging in along medial border of each foot (A) Anterior posterior x ray shows typical flatfoot architecture Forefoot is abducted as compared with posterior foot (B) Midline of astragalus points toward midline of body at an angle of about 45°, instead of straight forward toward great toe Scaphoid is lateral to head of astragalus In lateral x ray (C) midline of astragalus instead of pointing straight forward toward toes points almost straight down toward sole of foot Scaphoid instead of being directly in front of head of astragalus is facing superior surface of neck of astragalus Foot is broken in midtarsal joint so that this is the most dependent part of the foot Anterior end of os calcis is pitched downward instead of upward in normal position This girl was six years old when this picture was made Feet were corrected by a series of plasters and wedgings for two months and then feet were gently manipulated under an anesthetic and wedgings continued After three months of treatment plaster was removed swung in shoes applied and patient was given physiotherapy and instructions in walking properly (D) When seen last a year after treatment she was able to walk barefooted without arches touching floor

Fig. 73. Congenital flatfeet. Sister of patient shown in Fig. 72. She is two years old, and shows combination of congenital flatfoot and congenital clubfoot (A). X-ray of right foot (B and C) shows typical flatfoot type of deformity, as previously described. Flatfoot deformity was corrected by a series of plasters and wedgings, while clubfoot was treated in a similar manner. A swung-in shoe was applied to right and a swung-out shoe to left. Flatfoot deformity recurred and patient had a second course of treatment X-ray five years after beginning of treatment shows a nice correction of flatfoot deformity on right (D and E). Midline of astragalus in anteroposterior view points straight forward toward great toe, and in lateral view also points forward in almost normal position Condition five years after beginning of treatment shown in (F). Patient is not running her shoes over, and is walking nicely.

and to some degree dorsal convex The first metatarsal is usually straight, but articulates at its base with the mesial aspect of the inner cuneiform and makes a marked varus angle with the mesial aspect of the foot back of this point, the greatest concavity being between the scaphoid and metatarsal, and the cuneiform tending toward a lateral position with respect to the scaphoid.

There exists a similar condition with a mild forefoot adduction, which responds easily to treatment, and whose x-rays are not typical of the findings mentioned by Peabody, which probably should be called "metatarsus adductus." These probably belong in a class to themselves and are not to be confused with true metatarsus varus.

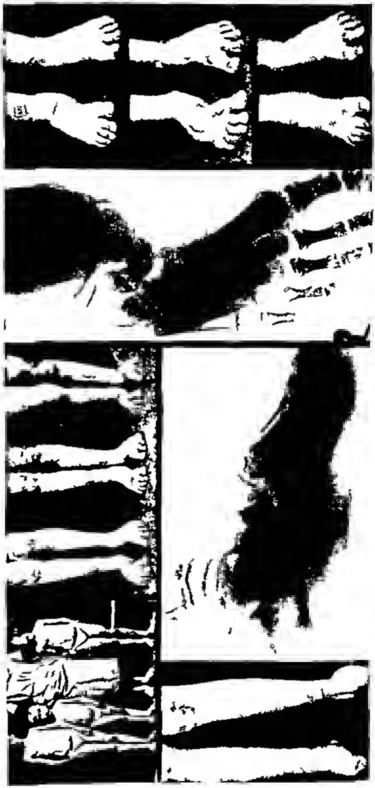

Fig 74 For legend see p 71

The deformity in true metatarsus varus is very difficult to correct, and when it has been apparently corrected it tends to rapidly recur I have treated all my patients first by a series of plasters and wedgings The plasters are wedged in abduction as for congenital clubfoot deformity Even in the older children a fair correction can be obtained after a while (Fig 74 F) These feet are held in the overcorrected position by swung out shoes which also have a wedge under the medial border of the heel, because of the valgus deformity of the posterior foot It is difficult to apply a plaster to correct the forefoot adduction without turning the heel out in more valgus However, with care in molding the foot as the plaster hardens, this can be largely avoided When the fore foot is wedged in abduction, the wedge shaped piece of plaster is removed farther forward on the forefoot than in the case of clubfeet In this way the forefoot can be abducted without turning the heel in valgus The wedge is placed forward so as to gain more correction in the metatarso cuneiform joints, instead of in the midtarsal joints, as in clubfeet In young children the deformity can be more easily corrected (Fig 75), and they retain their correction better All of the older patients have relapsed when treated by plasters and wedgings only Some of these have been given a second and even a third course of plasters and wedgings with fairly satisfactory feet None of the results in these cases is quite as good as those obtained by the same method with ordinary clubfeet

Treatment I have used various operative treatments Several types of wedge osteotomies have been done on the lateral side of the dorsum of the feet, going through the cuneiforms and cuboid, with the base of the wedge on the lateral border of the foot In one case with the double row of cuneiforms as shown in Fig 74, I simply took out the extra row of cuneiforms with a satisfactory result In another, I resected a portion of the shafts of the lateral four metatarsals and curetted the first cuneiform, so as to remove the internal structure and allow it to yield to the corrective force This allowed the forefoot to be placed in about

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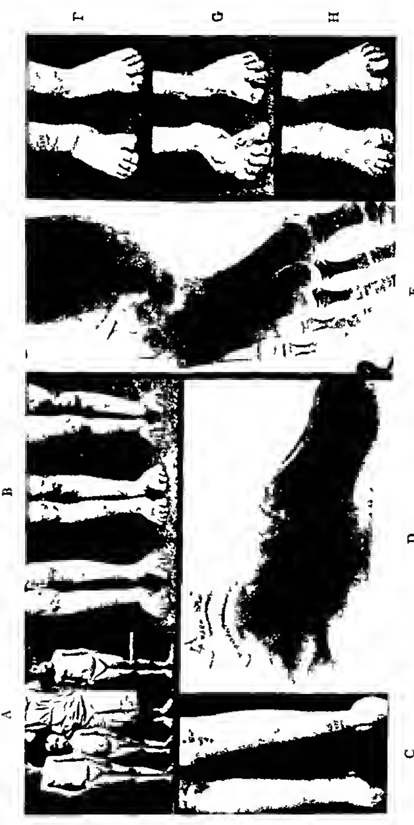
FIG 74 Congenital metatarsus varus A mother and three children with metatarsus varus are shown in (A) Children s feet are more typical than those of mother Three children all show typical metatarsus varus (B) Since this photograph was made two more children have been born and each had bilateral metatarsus varus making five children in this one family, all of whom have been treated In addition to forefoot varus they all showed extreme valgus deformity of posterior foot (C)

This entire family has presented several characteristics not mentioned in the recorded cases All have an abnormality of elbows There is a loss of the carrying angle with apparent dislocation laterally of head of radius with limitation of full extension and full pronation (A)

All children in this family show a double row of cuneiforms causing a very unsightly prominence on dorsum of each foot (D) Anterior posterior view better shows extra cuneiform for each of three cuneiforms and also that straight first metatarsal articulates with medial border of doubled first cuneiform (E) Middle three metatarsals are curved Anterior end of os calcis and head of astragalus are separated more than normal indicating that os calcis is rolled out from under astragalus in a flatfoot position Scaphoid is lateral to head of astragalus in a flatfoot position This patient was aged nine years when first seen He was treated by a series of plasters and wedgings as for clubfeet for five months Deformity was fairly well corrected for a child of nine (F) and swung out shoes were made for him

When next seen three years later, metatarsus varus deformity had recurred (G) being worse on right At that time a cuneiform osteotomy was done through middle of right foot with base of wedge on lateral border About eight weeks later a modified Hoke flatfoot type of stabilization was done to correct valgus deformity of heel Outline of foot has been restored to nearly normal appearance (H) Right heel is straight under tibia Patient was last seen 15 months after last pictures were made, and his feet are as well corrected as shown and he is working regularly in the field without discomfort



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the desired position I did this operation on one foot in a bilateral case and allowed the girl to go for a year She returned after a year and wanted the other foot operated upon to relieve the pain in this foot The operation had relieved the pain and had given her a fairly normal appearing foot The x ray of the first foot operated upon showed that the metatarsals had fused together, but that there was a space between the ends in some of the metatarsals so that better than those which were treated by plasters and wedgings

ARTHROGRYPOSIS MULTIPLEX CONGENITA

Children with congenital, multiple incomplete ankylosis of the joints of the extremities were first recognized and described as a separate clinical entity by Stern[16] in 1923 These children are frequently classed with congenital clubfeet but for the sake of prognosis and treatment it is most impor

A B C

FIG 75 Congenital metatarsus varus X ray of fifth child in family mentioned in Fig 74 made when patient was aged 12 months At birth her feet were crooked like those of three brothers and one sister (A) X ray (B) shows that shafts of middle three metatarsals are curved and point inward at an angle of about 45° to the normal position Head of astragalus and anterior end of os calcis are separated so that heel is in a valgus position Midline of astragalus points toward medial side of foot in a typical flatfoot manner Metatarsus varus was nicely corrected after five months of plasters and wedgings (C)

and the feet twisted The head and neck are not deformed or compressed, though there is a marked atrophy of the muscles of the shoulder girdle The limitation of motion does not seem to come directly from malformation of the joint surfaces nor is it due to multiple congenital contractures of the muscles and tendons The capsule of the joints and surrounding tissues, especially of the knees and elbows, seemed unduly thickened The limitation of motion in the joints is quite characteristic motion in the joints is quite free and unimpeded for a few degrees to either side of the center of the arc of motion Beyond this, both active and passive motions are impossible

In Stern's four cases, he said, "The feet are small and twisted, the toes short, pointed and compressed but not at all typical of congenital clubfeet' While these cases are not 'typical' of congenital clubfeet, they do present a clubfoot deformity The feet are smaller, and show a more marked deformity, and are more rigid They differ enough from typical congenital clubfeet that, after one patient has been treated the condition will probably never be overlooked

These children have all been slow in their mental and physical development They are slow to sit and walk, most have been slow in talking, and many have had a speech impediment Nearly all have shown deformities of the arms as described by Stern (Fig 76) Frequently the hands are compressed with the fingers and thumb drawn together In one boy the thumb dangled useless by the side of the hand In others the wrist is fixed in a flexed position, so that it has free range of motion in flexion until the wrist can be fully flexed (Fig 77 *center*) This same wrist can be extended only to within 90° of full extension (Fig 77, *bottom*)

Four of the 11 had congenital dislocation of one or both hips Two of these were reduced after some difficulty, and two could not be reduced at all even though the hip had been in traction for a long period before the reduction was attempted and even though several attempts were made at reduction The range of motion in these hips was so limited that they could not be flexed to a right angle and they could not be abducted more than a few degrees These two which could not be reduced got along surprisingly well later, because the stiffness of the hip seemed to stabilize it

Every patient showed some limitation of motion in one or both knees Lewin[17] in reporting two cases called attention to a 'diamond shaped position of the knees This is true if the child is held up for its picture, or if it is sitting with the knees partly flexed and the hips abducted but it is *not true if these same children are standing* In most of these children there is an outward rotation of the femur so that the patellae seem to be on the lateral side of the leg Because of the femoral torsion, the motion in the knee is transverse instead of in the normal vertical plane Most of these patients show an inability to get the knees in full extension This accounts for the diamond shaped deformity A few of these patients are knock kneed when standing

There is frequently a dimple over the elbows and the patellae (Fig 78) None of these cases shows a complete paralysis, though in many the muscles are weak None has shown exaggerated reflexes clonus, stretch reflex positive Babinski, or other evidence of spastic paralysis

Treatment This is one congenital deformity which looks promising in the beginning, but which is so difficult to treat that we are probably justified in recommending no treatment The treatment is usually directed first to the correction of the clubfoot deformity, as this is the most obvious deformity The treatment of these feet is the same as that used for congenital clubfeet, described in detail below Whatever it is which blocks the motion in these joints and prevents them from exercising the full range of motion, locks the various joints of the feet and prevents correction I treated one patient by plasters and wedgings for five years before finally obtaining satis

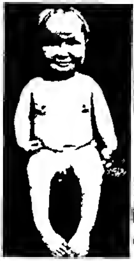

FIG 76 FIG 77 FIG 78

FIG 76 Arthrogryposis multiplex congenita This 26 month-old boy is a fairly typical case of arthrogryposis multiplex congenita, except for the feet, which have had six months' treatment in plaster elsewhere He can sit and slide, but has never tried to crawl on hands and knees and has never pulled up on his feet The flexion deformity of wrists is typical Femurs are rotated outward so that patellae are on lateral side of knees Feet are short, broad, and rather rigid

FIG 77 Arthrogryposis multiplex congenita (*Top*) These feet are fairly typical of this condition Thighs are rotated outward until patellae are on lateral side of leg Knees cannot be fully extended Feet show more inversion than average clubfoot, and present a condition which is different from ordinary clubfoot deformity Photograph was made at age 13 months at beginning of treatment Diagnosis is further established by limitation of motion in other joints, such as wrists When patient attempts to lift himself on his extended arms he does it with his wrist flexed as in the middle picture, which was made at age five He cannot place palm of his hand down in usual way, because wrist can be extended only a little beyond a right angle (*bottom picture*) Fingers can be hyperextended Little was accomplished by stretching this wrist with plaster and wedgings It required several courses of treatment by plaster and wedgings to correct these feet, because they relapsed each time they were released

FIG 78 Arthrogryposis multiplex congenita Photograph made at age two He was sitting alone, but could not pull up or stand No treatment had been given Both hips show marked limitation of motion Right is dislocated and has very little motion in rotation or abduction Femurs are rotated outward about 75°, so that patellae seem to be on lateral side of leg

This illustration shows dimple over patella, frequently seen in these patients Knees cannot be fully flexed and can be extended only to within 30° of full extension There is a slight depression about middle of left thigh suggesting a congenital contracture, but this is not very deep Feet are small and stiff and show more marked deformity than is seen in the average clubfoot even after years of weight-bearing These feet have never borne weight When they are held in the hand and an attempt made to correct them, they can be abducted only to within about 75° of midline

factory feet For others I have tried forcible manipulations under an anesthetic In several I have cut the ligaments between the bones of the feet which permitted the manipulation to accomplish more In others I have done a second bone operation and still do not have feet as good as those I have pictures to show a satisfactory correction of the clubfoot deformity in each of these cases However, they very quickly relapse and are soon back for more treatment

The knees are often fixed in a flexed position and allow only a few degrees of

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Fig 79

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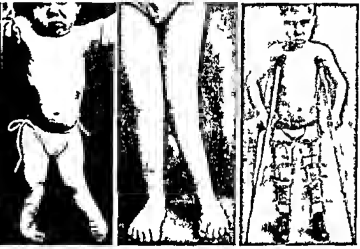

Fig 80

Fig 79 Arthrogryposis multiplex congenita This is a six month old patient In addition to extreme clubfoot deformity there is outward rotation of legs so that fold in popliteal space marking point of flexion of knees appears to be on medial side of leg (A) Knees go in recurvatum and can be flexed only 40° from full extension (B) Photograph made at age five It required four courses of treatment in the clubfoot clinic to correct these feet Feet are straight at age six (C)

Fig 80 Arthrogryposis multiplex congenita This patient was first seen at age 18 months (A) He also had a bilateral dislocation of both hips Hips could not be flexed to a right angle and had very little motion in abduction After several weeks in traction hips could not be stretched under an anesthetic or carried through any of the usual maneuvers necessary for a reduction Even though they could not be reduced they offer little handicap as they are fairly stable This patient was treated for five years in the out patient department by plaster and wedgings for correction of his clubfoot deformity (B) It was difficult for him to stand because outward rotation of femurs caused his knees to move from side to side instead of in an anterior posterior plane It was necessary to apply braces to stabilize knees (C) He then learned to walk actively with crutches, and his feet have held their correction for a year

obtained in the ordinary variety of club feet It takes so long to treat these feet that it is really a question if money donated to a charity institution should be used in treating cases which offer such a poor prognosis particularly since many of these children are also slow in their mental development

motion (Fig 79) The flexion deformity of the knees has been corrected by plasters and wedgings The knees in these children are often so unstable that braces are needed to hold the knees in full extension and in a good weight bearing position (Fig 80) The rotation of the femurs has been corrected in a few patients by osteotomies I have

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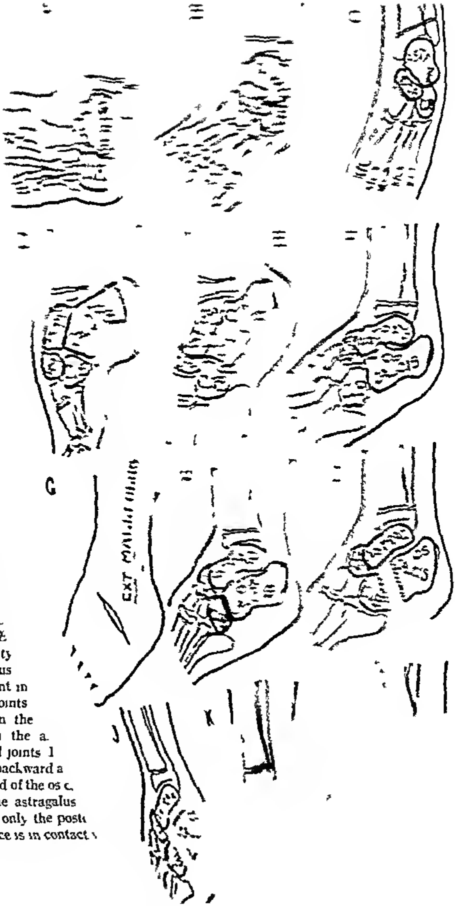

and function This is especially true if treatment is begun early in life

Treatment may be divided into *operative* and *nonoperative* methods

OPERATIVE TREATMENT OF CONGENITAL CLUBFOOT

The simplest operative method consists of forcible manipulations under an anesthetic This may be done manually, or over a *triangular* block placed under the lateral border of the foot, or with a Thomas wrench Some of the European museums exhibit machines which were used in times past in the correction of clubfeet These were designed to exert great pressure on the feet, so that the bones could be crushed and the foot set in a more nearly normal position Even in this modern time there are advocates for these ancient barbarous methods

With the advent of modern surgical technic, many different types of cutting operations were done on the fascia tendons ligaments and bones Most of these attacked the foot at one or two points, while every bone in the foot shows some distortion and all the ligaments are either stretched or contracted

Every incision is followed by scar tissue formation and some contraction Forcible manipulations also cause a tearing of the ligaments, injury to the articular cartilage and a crushing of the bones When the feet are held in plaster after the various manipulative treatments the bones often fuse into one solid block leaving the foot motionless This has been demonstrated by microscopic study of joints removed from feet which have been forcibly manipulated [18] This forcible manipulation at times gives a fairly good anatomic foot, but a very poor functional one If deformity should recur after such treatment, it is almost impossible to again correct it because of the bony ankylosis

If a brief description were given here of all the operations recommended for clubfeet, considerable space would be required and it probably would not be profitable To mention two of the more recent operations Brockman[19] avoids operation on the bones by making an incision on both the medial and lateral sides of the foot and separates the fascia and ligaments from the bones He cuts the tight tendons and ligaments until the foot can be placed in the desired position in plaster Two weeks later he lengthens the *Achilles tendon manipul* the foot in dorsiflexion and applies a new plaster

Curtis and Muro[20] recommend a decancellation operation for the correction of clubfeet The midtarsal joints are exposed by an anterolateral incision They describe their operation as follows

> The short dorsal flexor muscles are separated from their origin on the lateral side of the os calcis and retracted toward the top of the foot thus giving exposure of the neck of the astragalus anterior portion of the os calcis and the cuboid A small puncture wound is made in the three bones with successively larger curets the cancellous portion of these bones is removed All the cancellous bone is removed from the cuboid while in the os calcis and astragalus only the anterior portion is removed The foot is then forcibly overcorrected by manipulation with a Thomas wrench To correct the metatarsus varus and decrease the convexity of the outer border of the foot manipulation is done over a rectangular bar When visible collapse of the bones is not evident after manipulation the outer shell of the cortical bone of the cuboid and os calcis is split vertically with scissors to allow collapse If necessary in older children a section of the outer shell is removed from the bones mentioned and the articulating surface is not disturbed The first plaster is removed at the end of three weeks and under anesthesia a reapplication of plaster is made after the foot has been manipulated to the corrected position Plaster casts are applied in the overcorrected position for four months after which an inside upright and outside T strap brace is applied In the majority of the cases it was necessary to perform Steindler's operation before the decancellation and the lengthening of the tendo achillis The youngest child on whom the operation was

never done an operation to get more motion in any of these joints It is reported that these operations have been unsuccessful

Congenital Clubfoot

This is the most common of all congenital deformities A discussion of the etiology and pathology of a clubfoot will not be entered into here, as emphasis is being placed on treatment The types of clubfoot deformity associated with arthrogryposis multiplex congenita will be omitted, as they have been described above, and so will those cases showing an "absence of a part" of the foot, as they will be taken up later Congenital clubfoot deformity varies from very mild to very severe deformities, but on the whole it presents a fairly typical foot, with only a very few cases deviating from the average

In order that clubfoot deformity might be better understood, it is well to divide it into its three component parts (1) *Adduction* deformity of the forefoot The forefoot is drawn inward in relation to the posterior foot This motion takes place chiefly in the astragaloscaphoid and calcaneocuboid joints (2) *Inversion* deformity consists in a turning in of the entire foot This motion takes place chiefly in the astragalocalcanean or subastragalar joint No inversion occurs between the astragalus and the tibia, as the astragalus is securely locked in the mortise between the tibia and the fibula Inversion allows an elevation of the medial border of the foot (3) *Equinus* is the third element of the deformity, and may be divided into forefoot equinus and ankle equinus These are both present in the same foot but occur in different joints The forefoot equinus occurs between the forefoot and the posterior foot, in the astragaloscaphoid and calcaneocuboid joints In ankle equinus, the heel is drawn backward and upward, causing the anterior end of the os calcis to be pitched downward The astragalus is also plantar flexed, so that only the posterior end of the articular surface is in contact with the tibia, and the superior surface of the posterior end of the os calcis is almost in contact with the posterior border of the tibia

As the child grows older, the deformity becomes more fixed The ligaments on the medial border of the foot become more contracted The muscle pull, being in an abnormal direction, tends to increase the deformity As an example, the tendo achillis pulling on an inverted os calcis has a tendency to increase the inversion As growth takes place in the bones with the force falling in abnormal planes, the bones adjust themselves to the distorted position and the deformity becomes more fixed This distortion is further aggravated by weight bearing It is for this reason that treatment should begin at an early age

Treatment should be begun when the baby is about a month old It upsets a younger baby to carry it a long distance to a doctor's office The treatment is technically difficult and should be given by one who has been trained in the treatment of such cases After treating a large number of clubfoot children who have been partially corrected by their family physician, the records show that it has taken longer to correct these feet than it has to correct untreated cases If treatment is once begun, it should be continued until the foot is completely corrected, and the patient should be followed for many years and any recurrence corrected as soon as it can be detected It has been my observation that a partially corrected or relapsed clubfoot is more painful and more disabling than an untreated clubfoot For this reason no one should undertake the treatment of a clubfoot lightly

The result to be obtained, finally, depends almost entirely upon the type of treatment used Some operative treatments were designed to improve the appearance of the foot with apparently little thought as to function Nonoperative methods place function first and the corrected foot is practically as good as normal, in both appearance

and function. This is especially true if treatment is begun early in life.

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The simplest operative method consists of forcible manipulations under an anesthetic. This may be done manually, or over a triangular block placed under the lateral border of the foot, or with a Thomas wrench. Some of the European museums exhibit machines which were used in times past in the correction of clubfeet. These were designed to exert great pressure on the feet, so that the bones could be crushed, and the foot set in a more nearly normal position. Even in this modern time there are advocates for these ancient, barbarous methods.

With the advent of modern surgical technic, many different types of cutting operations were done on the fascia, tendons, ligaments, and bones. Most of these attacked the foot at one or two points, while every bone in the foot shows some distortion, and all the ligaments are either stretched or contracted.

Every incision is followed by scar tissue formation and some contraction. Forcible manipulations also cause a tearing of the ligaments, injury to the articular cartilage, and a crushing of the bones. When the feet are held in plaster after the various manipulative treatments, the bones often fuse into one solid block, leaving the foot motionless. This has been demonstrated by microscopic study of joints removed from feet which have been forcibly manipulated.[18] This forcible manipulation at times gives a fairly good anatomic foot, but a very poor functional one. If deformity should recur after such treatment, it is almost impossible to again correct it, because of the bony ankylosis.

If a brief description were given here of all the operations recommended for clubfeet, considerable space would be required, and it probably would not be profitable. To mention two of the more recent operations, Brockman[19] avoids operation on the bones by making an incision on both the medial and lateral sides of the foot and separates the fascia and ligaments from the bones. He cuts the tight tendons and ligaments until the foot can be placed in the desired position in plaster. Two weeks later he lengthens the Achilles tendon, manipulates the foot in dorsiflexion, and applies a new plaster.

Curtis and Muro[20] recommend a "decancellation" operation for the correction of clubfeet. The midtarsal joints are exposed by an anterolateral incision. They describe their operation as follows:

> The short dorsal flexor muscles are separated from their origin on the lateral side of the os calcis and retracted toward the top of the foot, thus giving exposure of the neck of the astragalus, anterior portion of the os calcis and the cuboid. A small puncture wound is made in the three bones ... with successively larger curets, the cancellous portion of these bones is removed. All the cancellous bone is removed from the cuboid, while in the os calcis and astragalus only the anterior portion is removed. The foot is then forcibly overcorrected by manipulation with a Thomas wrench. To correct the metatarsus varus and decrease the convexity of the outer border of the foot, manipulation is done over a rectangular bar. When visible collapse of the bones is not evident after manipulation, the outer shell of the cortical bone of the cuboid and os calcis is split vertically, with scissors, to allow collapse. If necessary in older children a section of the outer shell is removed from the bones mentioned and the articulating surface is not disturbed. The first plaster is removed at the end of three weeks and under anesthesia a reapplication of plaster is made, after the foot has been manipulated to the corrected position. Plaster casts are applied in the overcorrected position for four months, after which an inside upright and outside T strap brace is applied. ... In the majority of the cases it was necessary to perform Steindler's operation before the decancellation and the lengthening of the tendo achillis. ... The youngest child on whom the operation was

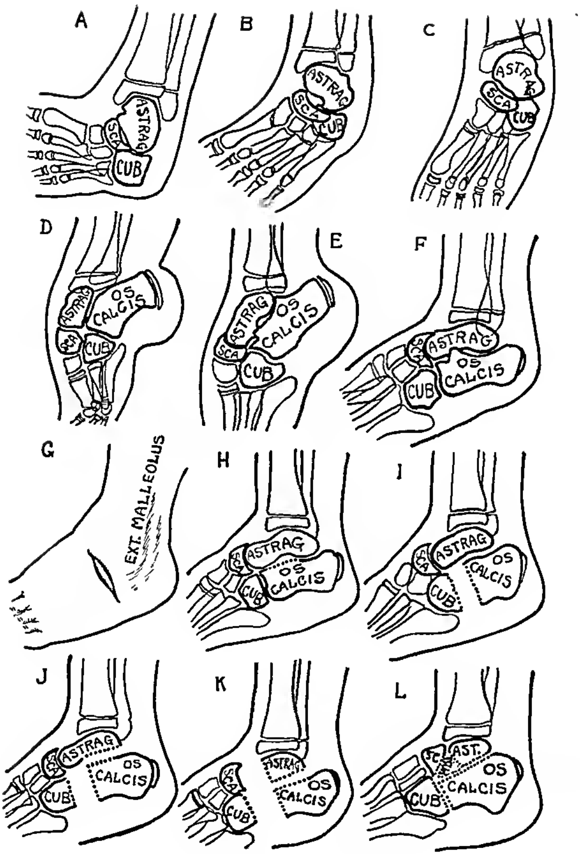

FIG. 81. For legend see p. 79.

done was one year old, while the oldest was nine years of age

The operation which I prefer for the severe neglected clubfoot deformity in children over six or eight is that which was devised by Hoke[14] for paralytic clubfeet. This operation does remove three of the joints of the foot, but it permits enough of bone to be removed to correct the deformity easily, without having to manipulate the foot and without doing damage to the other joints. It seems to me to be a less traumatizing procedure, and to be followed by less scar tissue, and I believe that it offers a much greater chance for successful correction. The clubfeet in the older children are usually fairly rigid before treatment is begun. We have seen many patients who have had this type of operation for infantile paralysis, without any undesirable stiffness. After using it for more than 15 years on these older clubfoot patients, it has proved to be a very valuable operation. Since no recent description has been given of this operation, it will be described in considerable detail here

In these older children with neglected clubfeet, I begin with the nonoperative treatment described below, and try to correct all of the forefoot adduction and inversion deformities by plasters and wedgings (Fig 81 A, B, and C). This may take several months. The feet are then brought up in dorsiflexion (Fig 81 D and E). If the equinus deformity is severe, the tendo achillis is lengthened and the foot wedged up further in dorsiflexion (Fig 81 F). By this time the badly deformed foot has been changed to a foot nearly normal in outline. The contracted ligaments and tendons on the medial border of the foot have been stretched, and those on the lateral border have contracted. The correction has not been complete enough for the foot to hold its correction if released, but it is in a position near enough to normal that an operation can be done which will easily complete the correction and maintain it[21]

FIG 81 Operative treatment of congenital clubfoot deformity. This series of tracings, made from x rays, shows operative correction of clubfoot. The anterior posterior x ray shows deformity before beginning treatment (A). Drawings are semidiagrammatic in order more clearly to show certain points. Scaphoid is medial to head of astragalus. This foot was treated by plaster and wedgings, with forefoot wedged in abduction (B). Forefoot was brought around in front of posterior foot until it was nearly corrected (C). When forefoot adduction had been corrected, lateral view of foot still showed extreme equinus (D), as no attempt had been made to correct equinus while adduction deformity was being corrected. The plasters were then wedged in dorsiflexion and some correction was obtained (E), but little progress was made beyond this point. Tendo achillis was then lengthened, and wedgings in dorsiflexion continued. This allowed fairly good correction (F). Foot would have relapsed had treatment been discontinued at this stage, as deformity had not been completely corrected. If an operation had been attempted when patient entered hospital, it would have been very difficult to have obtained a good foot. Now ligaments have been stretched on medial side, and foot is so nearly restored to normal that a good correction can be obtained by operation.

The Hoke clubfoot operation is done through a small incision on lateral border of foot (G). After carrying incision down to bone, anterior external corner of os calcis is removed, so as to give a better exposure for following steps (H). Calcaneocuboid joint is excised by a wedge-shaped excision with base of wedge on lateral border of foot (I). This will shorten long lateral border of foot, and permit correction of any forefoot adduction. Subastragalar joint is next excised by another wedge shaped excision with base of wedge on lateral border (J)—probably the most important step in the operation, as final alignment of heel will depend on accuracy of this excision. If too little or too much bone is removed, heel will not set straight under midline of tibia but will be in varus or valgus. Next step is to cut across neck of astragalus, just in front of articular cartilage on superior surface of body. Ligaments are cut about head and head and neck lifted out (K). Deltoid ligament is divided and cartilage curetted from scaphoid and about a third of neck and head replaced (L). This should be replaced medial to its original position as described. (Courtesy, Jour Amer Med Asso, 99 1156.)

If the Achilles tendon has not been lengthened during the preliminary treatment, it is now lengthened at the beginning of the operation by three partial transverse incisions as recommended by Hoke. The foot is then exposed through a lateral incision (Fig. 81 G) placed in the natural skin folds, extending from the peroneus tertius tendon downward to the peronei tendons, and a little proximal to the calcaneocuboid joint. The incision is carried directly through the deep fascia down to the bones. Some of the fat is removed between the fascia and bones for better exposure. The soft parts are dissected from the bones with a sharp periosteal elevator. The anterior external corner of the os calcis is removed for better exposure (Fig. 81 H). The calcaneocuboid joint is first exposed, and a liberal, wedge-shaped excision is made with the base of the wedge on the lateral border of the foot (Fig. 81 I). This wedge removes the anterior end of the os calcis and about one third to one half of the cuboid. It goes through to the scaphoid and head of the astragalus but does not include these. If sufficient bone is removed the forefoot adduction can be corrected later when the head of the astragalus has been removed.

Next the subastragalar joint is removed by another wedge-shaped excision, with the base of the wedge on the lateral border of the foot (Fig. 81 J). If sufficient bone is removed the os calcis is made to set straight under the midline of the tibia. Removing the proper amount of bone from this joint is probably the most important one step in doing the operation. If too little bone is removed, the heel is still left in a varus position, and if too much is removed the heel turns outward in a valgus position.

The next step is to cut through the neck of the astragalus just in front of the cartilaginous superior surface of the astragalus, and remove the head and neck of the astragalus (Fig. 81 K). This is carefully preserved for reinsertion later. The scaphoid can be seen on the medial side of the head of the astragalus. The cartilage is removed from the scaphoid, so that it may fuse with the head when it is replaced and better maintain the correction. In order to get the scaphoid around in front of the head of the astragalus, the deltoid ligament is divided by cutting through the tip of the tubercle of the scaphoid. By abducting the forefoot, the scaphoid can be brought forward and around with the rest of the forefoot, leaving a gaping space in the deltoid ligament. The cartilage is then removed from the head of the astragalus which has been lifted out of the foot, and from a half to two-thirds of the neck of the astragalus is cut away. The remains of the neck and head are replaced in the foot (Fig. 81 L). This time they are placed in a more medial position, so as to transmit the weight thrust straight forward from the body of the astragalus to the scaphoid and great toe. It is placed far enough on the medial side of the foot for the head to fit in the scaphoid.

By holding the foot in the midline and dorsiflexing it, one can tell by the sense of feel whether the head of the astragalus has been placed correctly. If it has not been placed over far enough to the medial side, the foot still comes up in a clubfoot position, and if placed over too far, the forefoot comes up in a flatfoot position. If placed in the proper position, the foot feels like a normal foot as it is dorsiflexed.

The portion of the neck which was cut away is now cut up in fine bone shavings and these are placed in any spaces between the bones about the body of the astragalus, head of astragalus, and scaphoid, so as to insure a better bony fusion. The deep fascia is then closed blood tight, if possible, by interrupted fine silk sutures, and re-enforced by an additional row of interrupted sutures in the subcutaneous tissue. If the foot was fairly well corrected before the operation it can be easily placed in the desired position. If it was in marked equinus, the foot should not be dorsiflexed to a right angle, because of the danger of stretching the pos-

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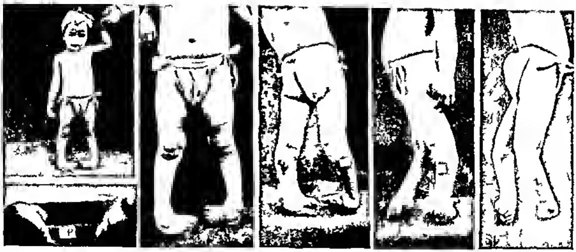
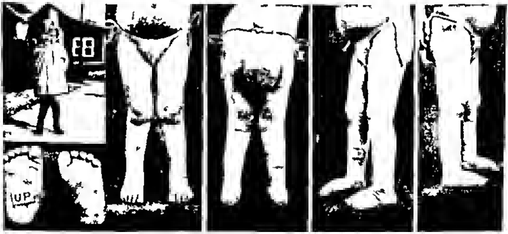


F B C D E

Fig 82 Congenital clubfoot deformity This is a three year old girl who has been put to sleep 27 times elsewhere, and her feet forcibly manipulated and plaster applied In spite of this she still presents a typical clubfoot deformity She walks with a wide base Has to step over each foot in reel fashion Cannot stand alone but has to be held to maintain her balance Weight is borne on lateral border of each foot and on dorsum of little toe No part of sole touches floor Sole faces backward and upward A bursa has developed on lateral border of each foot from walking The forefeet are adducted 90° There is inversion deformity and equinus deformity When feet are held in the hand they are rigid as result of previous forcible manipulations and the forefeet can be brought around only to within about 45° of midline Knees have also been stretched and are hyperextended about 45° past straight into recurvatum These feet are more difficult to correct than those of the average untreated three year old clubfooted child Her photographs are used throughout in illustrating the nonoperative treatment

A



F B C D E

Fig 83 Congenital clubfeet after correction by nonoperative method Same girl as shown in Fig 82 after eight months' treatment by plaster and wedgings She is now able to maintain her balance without being held Feet are normal in outline and set flat on ground Both heels seem to be directly under midline of tibia By keeping knees flexed in casts, recurvatum deformity was corrected These feet come well up in dorsiflexion She is wearing 'swung out' shoes which were made for her, and which were used at that time but are not used now

terior vessels and cutting off circulation The loss of circulation may be followed by gangrene and loss of a part of the foot The foot should be brought up about half way, and a plaster applied

In about two weeks a brief anesthetic may be given the foot brought up into the desired position and a new plaster applied No weight bearing is permitted in plaster After six weeks the plaster is removed and a straight last or a normal high top stiff leather soled shoe is applied These children need two or three weeks physiotherapy by which time they are able to walk without crutches and may be dismissed When this operation is accurately performed, it gives a very high percentage of successful results with very few relapses If the feet should relapse the same operation can be done again removing a little more bone where necessary and a successful correction obtained

NONOPERATIVE TREATMENT OF CONGENITAL CLUBFOOT

After observing the stiff feet which sometimes followed manipulation of clubfeet an attempt was made to devise some method which would give better feet I have published x rays which show a solid bony fusion between all the bones of the posterior foot ankle and tibia following manual manipulation which I did myself and which I thought I had done without the use of much force From a study of these operative cases it did not seem that the results could be improved by doing more accurately the operations which had already been described It seemed that a method should be used which would do less harm to the feet so I took the principles which were well known in the manipulative treatment and added patience and in 1924 corrected the first clubfoot in my series by plasters and wedgings These clubfeet were corrected without the use of an anesthetic and without any forcible manipulations or cutting operations It took a long time and considerable extra work, but the results were so pleasing that other clubfooted patients were tried In 1929 a report was made on 100 patients treated by plasters and wedgings [2] Since then I have personally treated over 400 clubfooted patients by this method and earnestly recommend it for those who are not seeking short cuts, but who are interested in getting the best results possible for these clubfooted patients It is probable that no major operation or other event in the individual s life will mean as much as the successful correction of the clubfoot deformity His ability to become a wage earning citizen depends upon the success of this treatment

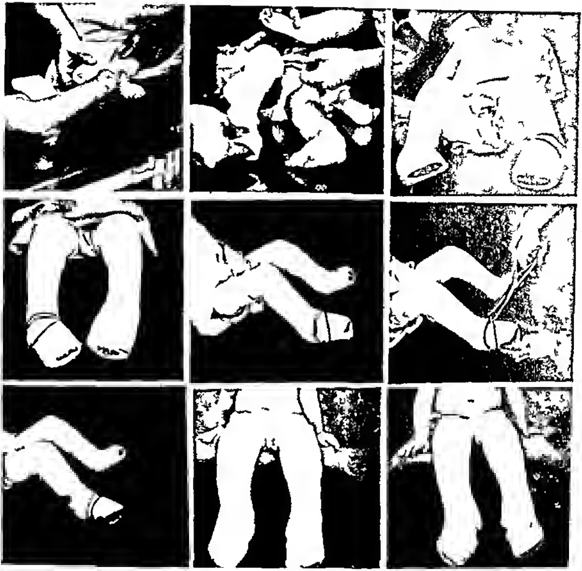
Ninety per cent of all clubfoot cases seen by me during the past 16 years have been successfully corrected by plasters and wedgings At no time during the treatment is the child given an anesthetic. At no time is the force used in correcting these feet enough to cause the patient to cry out with pain The correction is accomplished by a series of plasters and wedgings

Technic of Nonoperative Method This method might be best illustrated by taking a fairly typical case and following it through its entire treatment We will take a three-year old girl who has had 27 forcible manipulations under ether anesthesia elsewhere, and also several tenotomies There were scars over both tendo achillis and the soles of both feet The clubfoot deformity has relapsed so that the feet are now about like those seen in an untreated clubfoot patient (Figs 82 and 83)

The patient is placed at the end of the table The clubfoot is held by the surgeon and the plaster applied by the assistant When working with untrained assistants this procedure may have to be reversed but the important part of the treatment is holding the foot correctly (Fig 84) This cannot be done unless the one holding the foot has a clear idea of the anatomy of a normal foot and of a clubfoot and the principles involved in the correction of a clubfoot. It is

A B C

D



G H I

Fig 84 Application of casts and wedging in abduction Shows beginning of treatment on patient shown in Fig 82 Right foot is held by surgeon who places index finger of his right hand under side of great toe down to head of first metatarsal (A and B) He leaves his finger in this position while sheet wadding and plaster are applied This allows him a good grip on foot if child struggles and gives his assistant room to apply plaster Foot is held in abduction while sheet wadding and plaster are applied Plaster is continued upward to midthigh (C) Once or twice a week foot is wedged in abduction by removing a wedge shaped piece of plaster from lateral border of foot (D and E—*center*) Edges are turned up with a plaster turner to prevent pressure (F) Forefoot is abducted until patient shows signs of pain (G) The two segments of plaster are then joined together by a plaster bandage after manner described (H) On next plaster day, three days or a week later this last plaster bandage is cut and peeled off and foot is carried a little farther into abduction and another plaster bandage is applied in like manner (I) After two or three wedgings a complete new plaster is applied

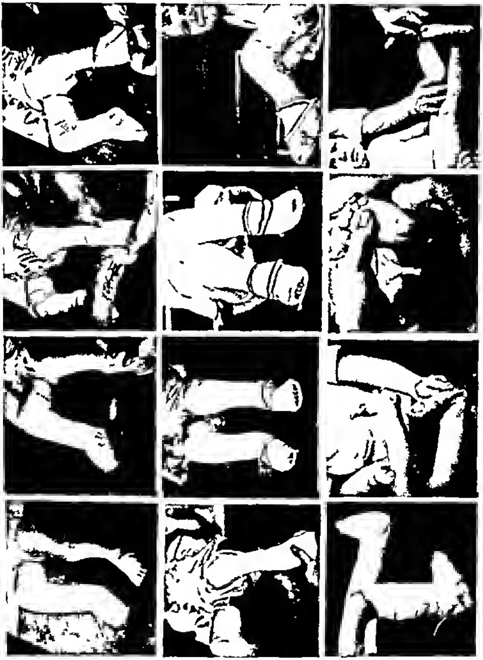


Fig 85 For legend see p 85

much easier to teach nurse assistants how to apply plaster correctly than it is to teach them how to hold the foot As stated in the beginning, it is necessary to correct the fore foot adduction first While this is being corrected, the inversion deformity can also be corrected, each time new plasters are applied Both of these deformities must be completely corrected before beginning dorsiflexion

CORRECTION OF FOREFOOT ADDUCTION The forefoot is abducted as much as possible, and is held in this corrected position while the sheet wadding and plaster bandages are applied The foot can be held best by the operator placing his index finger on the medial and under surface of the great toe, with pressure on the head of the first metatarsal With his thumb on top of the great toe he has good control of the foot (Fig 84 A) With his other hand he holds the flexed knee at a right angle to the table The thumb can be raised as the bandages are applied but the index finger is not removed until the sheet wadding has been applied to the leg and the plaster to the foot The sheet wadding must be applied smoothly and evenly, and very snugly This is the foundation for the plaster and it is as important that this be applied properly as it is that a building have a proper foundation Each edge of the bandage should lie flat on the leg and should not be allowed to pucker up in loose folds Edges of sheet wadding which stand out from the leg act somewhat like feathers in a pillow, and keep the plaster away from the leg and prevent the plaster from fitting as it should Small pads of three thicknesses of sheet wadding are placed over the points where pressure will come over the head of the first metatarsal, over the lateral surface of the foot, where the wedge will later be removed, around the back of the heel and over the top of the flexed knee (Fig 84 B) The sheet wadding is applied by circular turns, stretching the upper edge, when necessary, to make the lower edge lie flat It is continued up the leg as a spiral, overlapping two thirds of the previous turn and skipping one third No more padding is used than is necessary When applying the bandage of sheet wadding over a right angle as the heel or knee, it can be made to lie flat by first going over the center of the joint, and then making a figure of eight turn above and below, advancing away from the center of the joint The plaster should extend a little above the middle of the thigh, to prevent slipping and to prevent rotation of the proximal segment when it is cut for wedging

Many of these details may seem unimportant, and some may say that they should be omitted However, after seeing the plasters which have been applied in some clinics, it seems that these little details are important Little can be expected from a loose, ill fitting plaster There are some who say that plaster encasements cannot be applied to babies, because they slip off Others say

FIG 85 Wedging of plaster to gain abduction, and later dorsiflexion Same patient as in Fig 84 after plasters have been removed and a new one applied on right (A) Left foot is held in abduction by index finger of operator as described (B) A plaster bandage is applied to forefoot and another to posterior foot (C) Plaster is molded, and held until it has set (D and E) After plaster has been carried to midthigh it is marked for next wedging with an indelible pencil (F—*left center*) This is best done at time plaster is applied, while condition of feet is fresh in mind Frequently position of wedge is shifted a little farther forward or backward as indicated

When forefoot adduction and inversion deformities have been corrected, feet are wedged in dorsiflexion (G—*right center*, and H) Wedge of plaster is removed from instep Plaster is cut at level of malleoli This permits foot to be brought straight up into dorsiflexion as described After feet come up in full dorsiflexion they are held this way for eight to 12 weeks (I) When plasters are removed (J) parents are instructed how to stretch feet twice a day, first in abduction (K) if this is needed, and then in dorsiflexion (L) (See Fig 83 for result after treatment)

that plaster cannot be used because of pressure sores These statements admit a lack of skill in applying plaster It is the summation of all of these little details which brings success, and it is for this reason that many of them are mentioned

Two plaster bandages are first applied (Fig 85 C), one extending from a little beyond the toes backward on the forefoot, almost to the instep, and the second to the posterior foot and heel, making folds back and forth under the heel, so that the cast will be as thick there as elsewhere Care is taken not to let the plaster lap up on the instep as this might make pressure if the ankle is dorsiflexed after the plaster has set The assistant then holds the flexed knee perpendicular to the table, and the surgeon molds the foot into the desired position and holds it until the plaster hardens (Fig 85 D)

This is done most conveniently by grasping the toes with one hand, making them flat, and making light pressure on the head of the first metatarsal by the crotch of the thumb The other hand grasps the heel and pulls the heel outward as the thenar eminence of the palm makes pressure inward along the convex lateral border of the foot When the plaster has nearly set, a final molding can be done, by the surgeon shifting to the opposite side of the table, and again pushing the toes and heel outward while he makes pressure inward and upward with the fingers under the anterior end of the os calcis and cuboid (Fig 85 E) The foot must not be released until the plaster is hard, no matter how long it takes If this step is hurried a part of the possible correction will be lost "Impression" plaster which sets in three to five minutes should be used "Regular" plaster which hardens only after seven to ten minutes is unsatisfactory

After the plaster on the foot has hardened, the application is continued up the leg to the midthigh, with the knee flexed (Fig 85 F) The ankle is held in the neutral position, with no attempt to dorsiflex it The inversion deformity of the posterior foot is corrected as much as possible each time a new plaster is applied, until the heel is straight under the tibia

Wedging in Abduction A wedge shaped portion of plaster is removed with the base of the wedge on the lateral side of the foot The encasement is cut at the anterior end of the os calcis and again about an inch farther forward over the cuboid continuing the incisions around to the medial side of the foot in the region of the astragaloscaphoid joint, dividing the cast into two segments (Fig 84 D) The edges of the cut plaster are turned up with an instrument made for this purpose, to avoid pressure (Fig 84 F) The forefoot is then abducted until the child shows signs of discomfort (Fig 84 G), and the encasement is reunited with one plaster bandage (Fig 84 H)

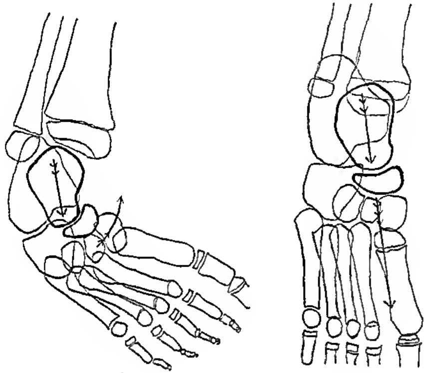
The details of applying this bandage are important (Kite,[71] Ghormley[73]) This bandage is started at the base of the great toe, crosses over the dorsum of the foot to the lateral side of the ankle and goes around the heel, and continues as a figure-of eight across the dorsum of the foot to the little toe and back under the foot to the starting point on the great toe This continues back to the heel, again going around the heel These turns draw the forefoot outward The bandage this second time is brought forward along the medial border of the foot to the great toe, and then around under the toes, on the edge of the cast under the toes, across to the little toe, and back to the heel It is this last turn which is drawn upon hard enough to make the proper amount of pull outward on the forefoot The bandage is carried around the heel, and the job is completed by applying the remainder of the bandage over the place in the encasement where the wedge has been removed The bandage must be kept low on the heel, so that the forefoot is simply abducted and not pulled up in dorsiflexion It is the strength of the gauze and not the hardness of the

plaster which holds the foot in correction

Wedgings are done twice a week on all patients in the hospital and once a week in the out patient clinic For those who live a long distance, wedgings are done every two weeks After a plaster has been wedged two or three times, a new one must be applied as more wedgings are apt to cause pressure sores In a very young baby the plaster should be changed every two weeks because of the rapid growth of the baby at this age

New plasters and wedgings are continued until the forefoot is carried out past the midline for some 30° or more The clinical test is to allow the foot to hang free when the plaster has been removed If it no longer swings back past the midline into adduction the adduction has been corrected A better test is to continue in abduction until the anteroposterior x ray shows that the adduction deformity has been corrected

When the forefoot adduction has been corrected, the scaphoid which was medial to the head of the astragalus will be found



A B

FIG 86 Mechanics involved in correction of forefoot adduction Tracings made from x rays of right foot of girl aged seven before and after correction of clubfoot deformity by plasters and wedgings X rays made before treatment show that weight thrust of body coming down tibia is transmitted forward through astragalus strikes obliquely on side of scaphoid and pushes forefoot around in adduction (A) When adduction deformity of forefoot has been completely corrected this weight thrust is transmitted straight forward from astragalus through scaphoid to toes as shown in tracing of x ray made after correction of forefoot adduction (B) If wedging of forefoot in abduction is stopped before scaphoid is directly in front of head of astragalus, deformity will recur when weight bearing is permitted, because weight thrust will fall obliquely on scaphoid as in (A) (Courtesy, Jour Bone and Joint Surg, 21 598)

around in front of the head of the astragalus (Fig 86) The weight thrust down the tibia is then transmitted through the astragalus to the scaphoid and straight forward to the toes If an attempt is made to dorsiflex the foot before the scaphoid is in front of the astragalus the scaphoid will be forced up on the medial side of the head of the astragalus If much force is used, the scaphoid may become fixed on the medial side of the head and later it will be found very difficult to change its position If the

The center of ossification for the scaphoid does not appear until about the fourth year When the scaphoid cannot be seen, the amount of correction can be determined by x ray, by observing whether the midline of the astragalus points toward the first metatarsal and great toe, or whether it points toward the middle of the foot If it points toward the great toe in the normal manner, the adduction deformity has been corrected

Correction of the *inversion* deformity is of sufficient importance to justify a detailed

Fig 87 Wedging of cast for correction of inversion deformity A wedge shaped portion of plaster is removed at about level of lateral malleolus, the cut in plaster is carried all the way around ankle freeing the two segments Base of wedge is on lateral border A plaster handage is started on medial side of lower leg about halfway between knee and ankle, and brought around under heel and up lateral border of leg Foot is everted, and tension on handage holds foot in eversion Bandage is then carried around leg in circular turns to fasten vertical turns to underlying plaster, and to fill in area where wedge has been removed

scaphoid is still on the medial side of the head, when the treatment is discontinued and the child is allowed to walk, the weight thrust will fall obliquely on the side of the scaphoid and push the forefoot back into the adducted position Fig 86 shows the mechanics of this and explains why forefoot adduction recurs when it has not been completely corrected If the forefoot is carried outward too far the scaphoid may be drawn around lateral to the head of the astragalus into a flatfoot position, which is undesirable Care should be exercised to correct the adduction deformity completely without overcorrecting it

discussion The value of thoroughly correcting this deformity was not fully appreciated until some six or seven years ago, and was not recognized when the patient shown in the illustration was being treated (Fig 89) At this time a study was made of a series of recurrent clubfoot cases It was found that the anterior posterior x rays of the feet which relapsed showed that the anterior end of the os calcis was rotated inward under the head of the astragalus, and that the feet had been brought up in dorsiflexion with this deformity still present

The inversion deformity is recognized in the anteroposterior x ray (Fig 88) by the

fact that the os calcis is rolled in under the astragalus, so that the shadow of the anterior end of the os calcis is directly under the shadow of the head of the astragalus When the inversion deformity is corrected,

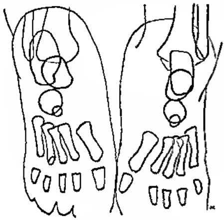


FIG 88 Showing correction of inversion deformity on right but not on left Tracings from x rays of a child with bilateral clubfoot, whose inversion deformity has been corrected on right but not on left Forefoot adduction has been corrected in each foot—indicated by fact that midline of astragalus is pointing toward first metatarsal and great toe We say inversion deformity has been corrected on right because os calcis has been rolled out from under astragalus, from varus to a normal position Shadows for anterior end of os calcis and head of astragalus are separated in normal manner On left these shadows are *superimposed, indicating that os calcis* is still rolled in under astragalus in a varus position Right foot is ready to be wedged in dorsiflexion Left foot should be wedged in eversion, until subsequent x rays show a separation of head of astragalus and anterior end of os calcis to about normal amount

the os calcis is rolled outward to its normal position, so that the anterior ends of the two bones are separated The midline of the astragalus then points toward the first and second toes, and that of the os calcis toward the fourth and fifth toes

CORRECTION OF INVERSION DEFORMITY When the plasters are applied for the correction of the adduction deformity, the heel should be gradually everted Care should be taken when successive plasters are applied not to carry the heel out past the midline of the tibia, because a valgus or flatfoot deformity may be produced If an antero posterior x ray shows that the deformity has been corrected, the foot is ready to be brought up in dorsiflexion If the x ray shows that the forefoot adduction has been corrected, but that the inversion deformity has not been corrected, the plaster should be wedged in eversion This step is not often necessary if the heel has been everted when the plasters were applied The base of the wedge is removed about the level of the lateral malleolus (Fig 87 *left* and *center*) The plaster bandage used to join the two segments of the plaster is started on the medial side of the lower leg and brought down under the sole of the foot, and up on the lateral side (Fig 87, *right*) By pulling the bandage, the foot is drawn out into eversion, and held in this position as the gap in the plaster is closed Encasements are changed after two or three wedgings, and the foot again checked with x ray

In making an x ray of clubfeet the center ray is directed straight down, without tilting the tube The patient lies flat on his back with his hips and knees flexed The knees are held together and must be straight *up, and not allowed to tilt to either side* The feet are held flat on the cassette by holding the great toes This keeps the fingers of the one holding the feet out of the way It hardly seems necessary to add that the feet should be held so as to show the maximum correction gained The feet should always be held by the parents, so that no one individual will get too much exposure to the roentgen ray In making the exposure the kilovolts should be increased, so that the exposure is a quarter of a second or less It is difficult to keep struggling babies still for a longer time A five by seven film is large enough to get an anterior-

posterior view of both feet, and is inexpensive

If the foot is brought up in dorsiflexion, with the heel in inversion, the os calcis will be held tightly under the astragalus in an inverted position The more force used in getting the foot up, the tighter these bones will be bound together in the deformed position It is physically impossible for these bones to correct this deformity spontaneously so the deformity persists When more pressure is used in trying to correct the equinus deformity the foot yields in the transverse tarsal joint, and a rocker bottom is produced in the foot

If it is not recognized that the heel is still inverted and if the foot is held for a long period in dorsiflexion with the os calcis in inversion adhesions form between the os calcis and the astragalus binding the two bones together so tightly that they cannot later be rotated to the normal position without operation In such cases, at the time of operation, it is difficult to introduce a periosteal elevator into the subastragalar joint, because of the adhesions

A study of these feet seems to substantiate the following statements When continued pressure is made on the bones forming a joint, in such a direction that the joint can move little harm is done to the joint When the direction of the force is such that the joint cannot move, or that the motion is blocked, the pressure causes atrophy, and, if the pressure is continued, the trauma will produce adhesions in the joint Later, if force is applied correctly, the deformity frequently cannot be corrected, because of the adhesions which bind the bones together It is for this reason that we should be sure that the adduction and inversion deformities are thoroughly corrected before beginning dorsiflexion

Correction of Equinus Deformity After the adduction and inversion deformities are completely corrected the foot is brought up in dorsiflexion, in order to correct the equinus deformity When the encasements are applied, it is important that pressure be made upward on the lateral border under the anterior end of the os calcis, as the plaster is molded to the foot, so as to preserve the arch It is the ankle equinus which is the most difficult to correct, so we should keep in mind the restoration of the os calcis and astragalus to their normal positions and not think so much about bringing the toes up toward the tibia The plaster is also carefully molded about the heel so that it will not slip away from the heel when the foot is wedged in dorsiflexion

The foot is *wedged in dorsiflexion* once or twice a week A wedge shaped portion of plaster is removed with the base of the wedge over the instep This is removed at the level of the malleoli, as shown in Fig 85 G and H, which leaves the plaster on the foot in the form of a low quarter shoe When the foot is brought up in dorsiflexion the motion takes place in the ankle joint If the wedge is cut with the apex over the tip of the heel as is sometimes done, the plaster will separate from the under surface of the heel, the foot will yield in the transverse tarsal joint, and a 'rocker bottom' will be produced With care this undesirable deformity should not occur, and it will not if the plaster is applied as described and wedged properly The two segments of plaster are joined together by a plaster bandage, using the same turns as before, only this time going around the back of the leg at a higher level so as to pull the foot upward The foot should be held in the midline, so that the maximum stretch is placed on the Achilles tendon If the heel is turned inward or outward it will produce a varus or valgus deformity After three or four wedgings a new encasement is applied, and the wedgings and plasters continued until the foot comes up as far as a normal foot, or preferably a little farther When the foot has been well overcorrected, it is held in

this position for eight to 12 weeks The plasters are changed every three weeks during this time, to make certain that the foot is held in the correct position, as it is easy to let the heel turn out in valgus or back in varus as the plasters are applied

This is probably the most difficult stage of the treatment in which to maintain the cooperation of the parents They realize that the feet are straight and are anxious for their child to begin walking and are tired of the trips to the office However, if it is properly explained to them that it is important to hold the feet in overcorrection until they begin to grow in this position, they will cooperate until it is time to remove the plasters

The children are never allowed to walk on their encasements for two reasons First, it softens them and renders them useless Second, when weight bearing is prevented, atrophy takes place rapidly in the bones and the correction is accomplished more quickly When the last plaster is removed, the parents are instructed in how to stretch the feet straight up into dorsiflexion for five minutes every night and morning The feet are brought up as far as they will come without too much pain and held for half a minute and then released This is repeated, bringing the foot up a little farther each time if possible Wiggling the foot or rubbing it does not do the good that stretching does The children are taught to voluntarily carry out exercises to hold the foot in the overcorrected position

A 'straight last" shoe is applied This is recommended because the 'in curve' of the average shoe tends to turn the foot back into a varus position None of the so called Clubfoot shoes have ever been used If the foot is well corrected, the child might go barefooted without fear of the foot relapsing If the surgeon cannot get the foot corrected, it is expecting too much of the shoe to do the job If "straight last" shoes cannot be obtained, the children should be fitted with high top, stiff leather soled shoes Usually the cheaper the shoe, the more nearly straight the inner border Shoes costing two dollars or less are worn by the clinic patients, and these seem to be as satisfactory as the more expensive shoes

These children should be seen in two or three weeks after they come out of plasters (Fig 83), and if the foot does not come well up into dorsiflexion, plasters should be re applied immediately At one time when it was noticed that the forefoot adduction was recurring, a "swung out shoe was advised, with a lift under the lateral border of sole and heel Now it is advised that plasters be re applied and the deformity be completely corrected The children should come back every month or two at first and then every six months to a year, and should be followed until past adolescence

When the feet have been corrected by the nonoperative method no damage has been done to the joints and the feet have practically as much motion as normal feet If the deformity recurs, they are easy to correct by repeating the same treatment since there are no adhesions in the joints This is not true after forcible manipulations and operations

Most of these patients can be treated in the office or clinic, so the cost of the treatment is less than the operative method, which frequently requires several admissions to a hospital The treatment by plasters and wedgings is a laborious method, but the surgeon is amply repaid by the improved results

It is necessary to complete the history of the patient shown in Fig 82, to give a 'typical' example of a clubfoot case and to illustrate what to do when the deformity recurs When the child is sent home with the feet corrected, the job is not finished This is especially true with feet which have been forcibly manipulated previously, and which have recurred previously

This patient lived more than 300 miles

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This patient lived more than 300 miles

from the clinic, and when she returned 20 months later the clubfoot deformity had recurred on the left (Fig 89) There was forefoot adduction some inversion and the heel lacked an inch from coming down to the floor This patient returned at the time we were x raying these feet to see why one recurred and one did not The x rays (Fig seemed to set straight under the midline of the tibia at the completion of the second course of treatment (Fig 91)

Even though repeated letters were written urging the parents to bring this child back for observation, it was four years before she was brought back She was now ten years old, and the left foot had relapsed

A B

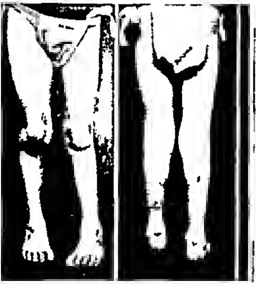


Fig 89

A B

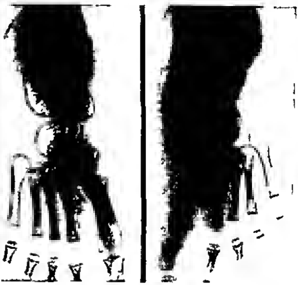


Fig 90

Fig 89 Recurrent clubfeet Shows condition of feet shown in Fig 83, 20 months later Right foot has held its correction but all three elements of a clubfoot deformity have recurred on left There is forefoot adduction some inversion of heel and equinus deformity so that patient cannot get heel to floor

Fig 90 X rays of recurrent clubfoot deformity When patient returned 20 months after treatment right foot was corrected, but left turned back into a clubfoot position This x ray shows that inversion deformity is well corrected on right Shadows for anterior end of os calcis and head of astragalus are separated about the normal amount On left os calcis is rolled in under astragalus so that the two shadows are superimposed showing that inversion deformity of heel has not been corrected on left Even though center of ossification for scaphoid cannot be seen at five midline of astragalus points toward great toe showing that forefoot adduction has been corrected

90) showed that the inversion deformity had been corrected on the right but that it had not been corrected on the left The patient was treated again by plasters and wedgings When attempts were made to evert the left foot it could not be brought out as desired because of adhesions in the subastragalar joint However, the heels but the right foot was satisfactory (Fig 92) An attempt was made to correct the deformity on the left with plasters and wedgings but little was accomplished An operation was then done The Achilles tendon was lengthened and a Hoke clubfoot operation was done as described above This gave her a nice correction of the left foot

She was seen last four years after the operation, at the age of 14 (Fig 93). She is not running her shoes over, has no trouble with her feet, and since they have held their correction for four years they will probably stay straight. It is interesting to compare the x-rays of these two feet at the age of 14 (Fig 94). The right, which was operative method is strongly recommended for the younger children, but for the 10 per cent who have bad treatment before or have been neglected and come late for treatment, operative treatment is necessary and the operation described has given very pleasing results It is certainly preferable to forcible crushing

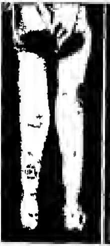


FIG. 91

FIG 92

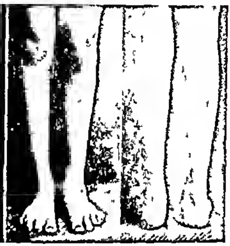


FIG. 93

FIG. 91. Result after a second course of treatment. Shows feet of patient shown in Fig. 89, after a second course of treatment by plasters and wedgings Both heels set straight under midline of tibia, and equinus deformity has been corrected

FIG 92. Relapse of clubfeet after second course of treatment. Shows that feet shown in Fig 91 have relapsed four years later. Right foot is still holding its correction, but left is running shoe over, and shows a slight forefoot adduction, some inversion deformity of heel, and equinus deformity. Patient is now ten years old. An attempt was made to correct left foot again by plasters and wedgings, but this was unsuccessful The deformity was then corrected by a Hoke clubfoot operation

FIG. 93. Result four years after operative correction on left. Same feet shown in Figs. 82 to 92. Deformity on right was corrected by nonoperative treatment, and that on left by operative treatment. She is now 14 years old and is not running her shoes over, and is having no trouble with her feet. She walks without a limp, but has a little loss of elasticity to the gait on the left

treated by the nonoperative method, shows practically normal architecture, with about the normal space between all the joints of the foot. The left foot shows the fusion between the calcaneocuboid joint, the subastragalar joint, and the astragaloscaphoid joint. The right foot has more motion, and more elasticity when she walks. The non-

CONGENITAL ANOMALIES OF TOES

The most common congenital variation of the toes is polydactylism, or supernumerary digits Other anomalies which may require treatment are syndactylism, macrodactylism, congenital contracture, and congenital absence of toes or parts of the foot.

Polydactylism

Polydactylism is an increased number of toes This usually consists of only one extra toe, but at times there may be double the usual number (Figs 49 aod 51) There may be as many extra metatarsals as there are extra toes or the extra toe may be an out

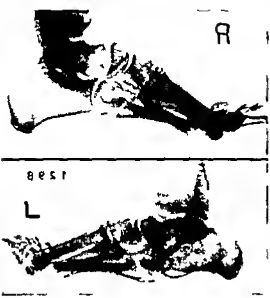


Fig 94 X rays after clubfoot treatment X rays made at age 14 of girl shown in Figs 82 to 93 Right foot, which was treated by nonoperative method shows practically normal architecture, with about normal amount of joint space, indicating that little or no harm has been done by treatment Left foot shows result of operation four years previously, in which calcaneocuboid, subastragalar, and astragaloscaphoid joints were fused Superior surface of astragalus in each foot is flatter than normal which limits full ankle motion This probably followed the 27 forcible manipulations she had when a baby

growth from the distal end of a normal or "Y" shaped metatarsal The extra toe may be on the great toe side (Fig 95), or on the little toe side (Fig 96) This deformity is always present at birth, shows a very definite tendency to run in families, and may be traced back for several generations

Treatment is required because the extra toe makes the foot too large to go comfortably into regular shoes These childreo come for treatment after they have been wearing shoes for several years, and after they have tried tennis shoes and oversized shoes without relief An x ray should first be made to determioe if there is an extra metatarsal as this should be removed if it increases the width of the foot It usually is not difficult to tell which is the extra toe This is removed by a circular incision about the base of the toe The tendons are drawn down as far as possible and severed The capsule of the proximal joint is cut across, and the toe disarticulated Any protruding bone should be removed with a chisel or bone forceps, so to leave a smooth surface Enough bone should be removed to reduce the foot to the normal size Operative treatment is a very satisfactory procedure in this condition and is followed by complete relief (Fig 97)

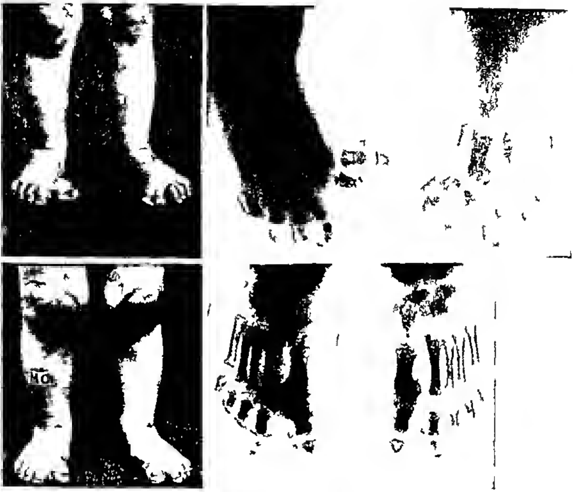
Syndactylism

Syndactylism is a webbing of the toes and seldom needs to be corrected When it involves an extra toe, the extra toe is separated (Fig 95) The methods of correction would be the same as for separating webbed fingers [For procedure, see p 3]

Macrodactylism

Macrodactylism is an overgrowth of one or more toes The child is born with the deformity The enlarged toe may increase io size out of proportion to the rest of the foot Sometimes the enlargement is due to a lipoma, but this is present at birth Several varieties are shown under congenital hypertrophies (Figs 37, 38, and 39) The patient shown in Fig 39 had very unusual feet The x ray of her feet shows the tremendous enlargement and elongation of the second and third toes (Fig 98) It was necessary to amputate the second and third toes so that she could wear shoes

A B



D C

FIG 95 Polydactylism and syndactylism double great toe on each foot Numerous relatives of this child have a similar condition Father has never had an operation He is unable to wear normal shoes and has to have them specially made even then he suffers from pressure on his toes The child is unable to wear normal shoes because of pressure on her great toes (A) The great toes have fused (syndactylism)

X ray shows that she has only five metatarsals and that the extra toe has grown out from a deformed first metatarsal (B) The extra great toe was removed by separating it and amputating the toe (C) Nothing was done to the metatarsal Remaining great toe was bandaged snug to other toes following operation Foot was reduced to the normal size and outline (D) and she was able to wear store shoes without discomfort

Congenital Contracture or Angulation of Toes

Congenital contracture or angulation of the fifth toe on top of the fourth toe is seen occasionally This is frequently hereditary

A B

Fig 96 Polydactylism extra little toe bilateral This boy aged ten was born with six fingers and six toes on each side Extra fingers were removed shortly after birth He has great difficulty in wearing shoes because of pressure on sixth toe on each foot (A) Extra little toe on each foot was amputated (B) He is now able to wear normal shoes with no discomfort

A similar contracture of the little finger is frequently seen in mother and child The overlapping of the fifth toe on the fourth may cause no discomfort, especially in boys but girls often complain as they wear much narrower shoes (Fig 99) In the patient shown it was found that the extensor tendon to the little toe was contracted This was lengthened by a plastic operation and a plaster applied with the toes plantar flexed After the operation she was able voluntarily to flex the toes She received a short period of physiotherapy A year later she had a satisfactory result She could not flex the fifth toe quite as far as the others but was free of the pain from pressure

Congenital Absence of Toes

A congenital absence of one or more toes is usually associated with an absence of the corresponding metatarsal The missing toe is usually on the lateral border of the foot This deformity is frequently associated with some other deformity of the foot, as club foot deformity (Fig 100) Clubfoot deform

A B C

Fig 97 Polydactylism inadequate operation This boy was born with six fingers and six toes on each side Family physician amputated extra finger and extra toe on each side when patient was seven weeks old Patient at age of six still cannot wear leather shoes because of discomfort from pressure about little toes (A) X ray shows an extra rudimentary phalanx on right representing a part of the extra toe which was not completely removed (B) On left there is a Y -shaped fifth metatarsal with a part of the extra phalanx It is quite evident that an inadequate operation was done Remaining portion of sixth toe on each side was removed On left a part of branching fifth metatarsal was also trimmed away Patient has had no further trouble with his feet (C), and wears normal shoes with comfort

Fig 98

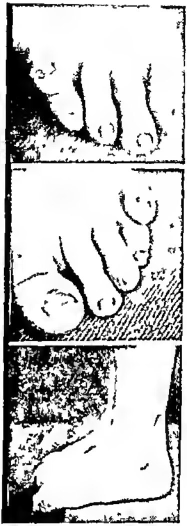


Fig 99

Fig 98 Macrodactylism X ray of feet of girl shown in Fig 39 Parents first objected to operation, so special shoes were made for her These proved to be too expensive, so consent was given for operation, and the hypertrophied second and third toes were amputated, reducing length of foot so that she was able to wear normal shoes X-ray shows that shafts of second and third metatarsals are considerably longer than normal, and that they have taken most of the weight in walking as they are denser than normal, while first metatarsal shows slight atrophy as compared with the one on right Hypertrophy also involves phalanges of second and third toes

Fig 99 Congenital contracture of toes (dorsiflexion) At birth each little toe was on top of the fourth toe (*top and center illustrations*) She suffered constantly from pressure of shoes on these toes, and at age 13 came for relief Extensor tendons were found to be contracted These were lengthened by a plastic operation Three partial transverse incisions were made in tendons similar to method used to lengthening Achilles tendon After operation, patient was able to voluntarily plantar flex her toes (*bottom illustration*) When seen a year later she was wearing normal shoes in comfort

FIG 100 Congenital absence of toes Father and mother have normal feet Patient was born with both feet clubbed (A), and with an absence of fourth and fifth toes on right and fifth toe on left (B) There is an absence of astragalus and cuboid on right, as well as fourth and fifth metatarsals (C) Os calcis is fixed in extreme equinus On left, cuboid is fused to os calcis (D) Posterior foot is in extreme equinus Clubfoot deformity was corrected by a series of plasters and wedgings It was more difficult to correct equinus on right than on left Since there is no astragalus on right, right foot has had a persistent tendency to turn back into a varus position when it has been left out of plasters For this reason it has required much longer to correct this foot (E) than it requires for an average clubfoot

ity accompanied by a loss of part of the bones in the foot is much more difficult to correct than a clubfoot which is not deficient in any of the parts When these feet are corrected, they are much more prone to recur Nothing can be done about the loss of the toes The problem is that of correcting whatever deformity is present, and this is done by plasters and wedgings Usually smaller shoes are needed or if the deformity is unilateral (Fig 101), mismated shoes In the unilateral cases the leg affected is usually smaller and a cork lift may be needed as the child grows older

A B C

FIG 101 Congenital absence of lateral four toes and corresponding metatarsals Patient presented a clubfoot deformity on right, in addition to congenital absence of lateral four metatarsals and toes (A) Only first metatarsal and great toe were present in forefoot Remainder of forefoot appeared to be a pad of fat and soft tissue

Clubfoot deformity was corrected by a series of plasters and wedgings but required longer for its correction than an average clubfoot (B) He has held his correction nicely a year and a half after treatment (C) Right leg measures 3 5 cm shorter than left at age three He wears mismated shoes but no lift as yet

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4

Congenital Dislocation of Hip

A H Brewster, M D

The first accurate description of congenital dislocation of the hips was by Agostino Paci of Pisa He reported 24 cases at the Ninth International Congress in Rome in 1894 Previous to this report no series of cases were reported There were only sporadic reports which are of no value Since Agostino Paci s report in 1894 the subject has received the attention of a vast number of observers in all parts of the civilized world

[The following excellent brief resumes of theoretical etiology, embryology anatomy, and signs and symptoms are allowed here to stand since their bearing on treatment rationale and prognosis and on interpretation of results, while in many instances not direct, is nevertheless definite —Ed]

ETIOLOGY

The etiology of congenital dislocated hip or hips is unknown Many theories have been advanced, any one is just as good as another Some of the theories advanced are

1 A failure in the correct embryologic development of the acetabulum, the capital epiphysis, and the capsule of the hip joint

2 Fixed position in utero conducive to the development of dislocation of the hips

3 Failure of the epiphysis at the superior margin of the acetabulum to develop This theory was advanced by L B Morrison [1]

4 In recent years Vogt has contended that congenital dislocation of the hip is a postnatal condition due to inherent relaxation of tendon and ligaments [2]

EMBRYOLOGY

According to Dr Leo McDermott [3] in the 6 75 mm (3 plus wks) embryo are found the limb buds filled with mesodermal cells indistinguishable from one another In the 10 mm (4 plus wks) embryo the sciatic nerve and femoral artery can be distinguished in the 15 mm (5 6 wks) embryo the region of the hip joint is shown as dense blastema and the femur can be recognized as containing precartilage At 17 55 mm muscle groups can be recognized about the femoral shaft and in the region of the greater trochanter The femur is fairly well outlined and contains cartilage cells The ilium and pubis can be identified At 19 3 mm (7 wks) angulation at the upper end of the femur outlines the femoral neck The acetabulum and femur comprise one mass until the joint space opens The acetabular fossa can be recognized in the 22 8 mm embryo and within it the origins of the ligamentum teres and the Haversian gland are recognized In the 23 mm embryo the joint line appears as a zone of diminished density in the blastemal cells All of the primordia of the innominate bone can be seen The neck of the femur shows more angulation Ligamentum teres is recognizable At 28 8 mm the origin of the ligamentum teres from both pubis and ischium is shown within the acetabular fossa At

30 mm the glenoid labrum is well developed and angulation of the femoral neck is increased The ligamentum teres arises by disappearance of cells from the blastemal tissue within the region of the acetabular fossa leaving this structure At 36 mm spaces can be seen in the tissue about the head of the femur The ligamentum teres is closely applied to the femoral head At 44.3 mm the joint cavity is quite well developed, the capsule recognizable, and numerous vessels are seen in the Haversian gland, the ligamentum teres, retinacula of Weitbrecht At 77 mm vessels can be seen entering the neck of the femur through small lacunae hollowed out of the cartilage beneath the retinacula At 167 mm vessels are recognized in the head and neck of the femur and some can be demonstrated entering through the ligamentum teres The acetabulum is relatively shallow in comparison with the head In acute flexion at this time, the head of the femur seems to press on the joint capsule outside the transverse acetabular ligament inferiorly The elements of the hip joint develop from one mass of blastemal tissue, and for this reason it is unlikely that dislocation could occur before the development of the joint space

ANATOMY

The normal acetabulum is made up of a pubic and ischiatic portion The ilium also helps in making the acetabulum At an early stage we have the epiphysis, and a great part of the above named bones are cartilaginous The capital epiphysis of the femur, the epiphyseal line, and the neck of the femur are also anatomic landmarks The capsule of the hip joint is also a very important anatomic structure The ligamentum teres is another anatomic structure of importance in all instances

Robert Soutter and Robert W Lovett make the following statement[4]

> In normal hips, the acetabulum is made up of a pubic and an ischiatic portion, which develop one faster than the other In 90 per cent of all cases previous to the second birthday, the iliopubic and ischiopubic portions were as 1 1 After the second birthday, 75 per cent of all cases showed a relation of 2 3, so that the acetabulum develops chiefly from the ischiopubic portion, especially after the child begins to walk
>
> In 11 per cent of normal cases the upper rim of the acetabulum is very oblique in 56 per cent oblique, and in 33 per cent slightly Between 1 and 2 years of age 26 per cent are oblique Beyond the second year no acetabulum is oblique in the normal The oblique shelf is probably not abnormal before the child begins to walk
>
> The capital epiphysis of the femur does not appear as a rule before six months The relative proportion varies at different ages In children from six months to 3 years, 50 per cent are two parts capital epiphysis and one part neck, while 33 per cent are three parts capital epiphysis and one part neck and 16 per cent are one part capital and the neck one part Beyond the fourth birthday the articulating head is composed as a rule, of four parts capital epiphysis to one part neck The capital epiphysis develops very much faster than the neck in forming the ultimate articulating head of the femur
>
> In a study of the capital epiphysis (that part above the epiphyseal line) the normal ultimate head broadens and is formed from the capital epiphysis and the neck, the capital epiphysis portion increasing twice as fast as the portion formed from the neck
>
> The angle of the neck, according to Dwight,[5] is about 160 degrees and decreased toward puberty to 125 degrees
>
> Soutter and Bradford[6] in a large series of normal hips report 50 degrees of antetorsion to 0 degrees with an average of 14.3 degrees They quote Mikulicz with a series of + 37 to + 25 and an average of + 11 6, and Broca with 38 to — 2 but no average
>
> The femoral neck up to the second birthday is short With growth it gradually becomes longer and more slender, and there is a definite decrease in both angle and torsion As a rule, the shorter the neck, the broader it is (This was noted in the normal and dislocated hip as well)
>
> A summary of the conclusions of the hips in normal children shows that the acetabular shelf is originally slightly oblique upward and outward, and grows horizontal at the age of weight bearing The capital epiphysis appears about the sixth month as a small round body

which is separated from the neck by a nearly horizontal line, and no segmentation of the epiphysis is observable

The articulating surface of the head is usually made up of two portions from the femoral epiphysis and one portion from the neck The effectiveness of the acetabular shelf varies, 90 per cent being about normal

In a child, the femoral neck is broader and shorter, with a higher degree of torsion and angulation than appears in adults

The articulating surface of the head appears to be more largely made up from the capital epiphysis and a little from the neck

PATHOLOGY

Any deviation from the normal anatomy of the hip joint must be considered pathologic Increased obliquity of the shelf of the acetabulum, abnormal shape of the head and neck of the femur, hourglass contraction of the capsule, elongation of the ligamentum teres, and delayed ossification of the capital epiphysis are the most common pathologic conditions met in congenital dislocation of the hip, and must be considered in prognosis or treatment

FREQUENCY

In a comparatively recent unpublished report of 126 cases by Delbert Hand [7] there were 176 dislocated hips Of this number 89 per cent were females and 11 per cent were males Bilateral involvement was present in 39 per cent of the cases, unilateral in 61 per cent, the right hip alone was involved in 25 per cent of the cases, and the left alone in 36 per cent Other groups of reported cases agree with these figures

To facilitate the discussion of treatment, it seems wise to divide congenital hip or hips into the four groups of patients that follow

1 From birth until the age when walking begins

2 From the age of walking up to three years

3 From the age of three years up to six years

4 From six years on

GROUP 1 FROM BIRTH UNTIL WALKING BEGINS

Signs and Symptoms It has been only in recent years that the diagnosis of congenital dislocated hip or hips has been made before the patient walks The advent of the x ray made it possible to prove the diagnosis when such a condition was suspected clinically after the age of six months when the femoral epiphysis showed calcification The most important clinical signs of congenital dislocated hip in a child who has not walked are in single dislocation

1 Increase in the number of folds in front and back of the thigh as compared to the normal side There is usually one fold in a normal hip both front and back whereas in a dislocated hip there are two or more folds front and back, two being the usual number (Fig 102)

2 Increase in all motions of the hip joint except abduction as compared to the normal hip

3 The greater trochanter is above Nelaton's line (a line drawn between the anterior superior spine and the tuberosity of the ischium)

4 There is piston motion in the dislocated hip, that is, the head and trochanter can be pushed up and down This does not occur if a hip is in joint

5 As a rule, if the child is recumbent on the back, the leg on the side of the dislocation is held in a position of external rotation just like that which is seen in a fracture of the neck of the femur in an older person

6 If the child is placed on its back in a recumbent position with the knees flexed so that the soles of the feet rest squarely on the table, the knee on the dislocated side will be lower than the knee on the normal side

7 X rays do not help because there is no way of determining whether the greater trochanter or trochanters are above Nelaton's line (Fig 103)

8 X ray of a child under six months will

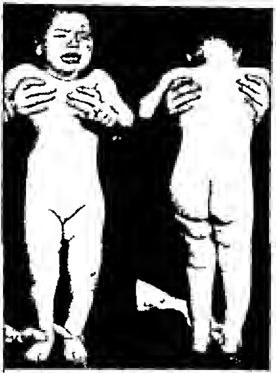


FIG 102 (*Top*) Left hip dislocated showing multiplicity of folds in front and back Folds are much deeper on left and a third fold appears on that side Front view is very convincing

FIG 103 (*Bottom*) X ray taken at age three weeks It is impossible to determine whether one or both hips are out of socket It happens that both of these are out of socket At this age the capital epiphysis cannot be seen by x ray If a single dislocation were present, the trochanter on that side might be higher

show the greater trochanter higher than that on the normal side, but the capital epiphysis has not ossified up to this age and does not appear in the x ray

9 X ray after six months up to the age of walking will show the trochanter high and the capital epiphysis will appear to be out of the acetabulum

The signs in this group when both hips are dislocated are, for the most part the same as when only one hip is dislocated The multiplicity of folds in the front and back of the hip is bilateral There is an increase in all motions of both hips except in abduction Both greater trochanters are above Nelaton s line If the patient is placed on its back in recumbency and the knees and hips are flexed so that the soles of both feet rest squarely on the table, the knees will be level If one hip alone is out of joint the knee on the side of the dislocation will be lower than the knee on the normal side If a patient with bilateral dislocated hips is placed on his back recumbently on a table, both legs will usually be externally rotated only one will be externally rotated in a unilateral dislocation Clinical examination in bilateral cases taken before six months of age shows only that the trochanters are above Nelaton s line At this age the capital epiphysis does not show, since ossification has not begun X ray after six months of age and up to the age of walking in bilateral cases will show not only the trochanters to be high but also both capital epiphyses to be out of joint Usually there are no symptoms, no discomfort, and no pain

GROUP 2 FROM AGE OF WALKING UP TO THREE YEARS

Signs and Symptoms It is during this age that most of the cases come for diagnosis and treatment This is
true around the medical
United States The signs in t
very similar to those in
birth to the age of walkir
ing difference is that

tory, and this brings out a most striking sign If one hip is out, when the patient walks he has a unilateral waddle gait This waddle gait is due to the fact that when the patient puts weight on the affected side, the head of the femur, having no shelf over it, rides up on the ilium In addition, in a single hip the Trendelenburg is positive when the patient stands on the affected side In bilateral dislocation, the Trendelen burg sign is positive when standing on




Fig 104 Fig 105 Fig 106 Fig 107

Fig 104 Double congenital dislocation of hips in a child under three Note marked lordosis and double fold in each thigh

Fig 105 Bilateral unreduced congenital dislocation of hips Photograph shows prominence of abdomen and extreme lordosis

Fig 106 Child in plaster after left hip has been reduced Note plaster on right goes only to knee

Fig 107 Posterior view of unilateral dislocated hip in plaster This is a right congenital dislocated hip

either leg In the bilateral cases, there is very definite increase in the lumbar lordosis X ray in this group will show the trochanter high and the capital epiphysis out of the acetabulum This picture is the same on both sides if both hips are dislocated There are usually no symptoms in this group, but many signs (Figs 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, and 114)

GROUP 3 FROM AGE OF THREE YEARS UP TO SIX YEARS

Signs and Symptoms (Fig 115) In this group more patients present themselves for diagnosis and treatment than in any other group except Group 2 The signs in this group are exactly the same as in the group above mentioned except that piston mobility may not be so marked and the waddling gait has a tendency to de crease slightly The lordosis, so marked in the bilateral cases as a rule, is more marked in this group Occasionally the child will complain of fatigue due more to the limp Complaint of pain is rare

GROUP 4 FROM SIX YEARS ON

Signs and Symptoms As above men tioned, this group includes individuals with one or both hips out of joint at birth who have reached the age of six and beyond this age, where no effort has been made to re duce the hip or hips Such a group presents a problem far more difficult than Groups 1, 2, or 3 Changes have taken place in the acetabulum, the head and neck of the femur, and the ligamentum teres, as well as the capsule of the hip joint In all likelihood the ligamentum teres will have elongated

The capsule will coostrict io its middle and produce an bourglass appearance The capital epiphysis of the femur, after years of undergoing abnormal mechanical physiology, becomes distorted It becomes evident witb the above difficulties, both physiologic and pathologic, tbat reduction of a tive in both unilateral and bilateral dislocations Piston mobility is present but likely to be less than it is in Groups 1, 2, and 3 When this age group is reached, the multiplicity of folds in the buttocks may, to a certain extent, have disappeared or be not so noticeable (Fig 115) In both uni

Fig 108

Fig 109

Fig 110

Fig 111

Fig 112

Fig 113

Fig 108 Front view of child under age tbree who has had botb hips reduced and is in plaster The plaster in front could be cut much lower

Fig 109 Back view of child under age tbree who bas had botb bips reduced and is now in plaster

Fig 110 Child in Group 2 Bilateral congenitally dislocated hips Reduced before age tbree Picture shows that there is oo Trendelenburg Same patient had a positive Trendelenburg sign when standing on right leg

Fig 111 Same patient as in Fig 110 Child witb bilateral congenital dislocation of hips who was under age three at time of reduction Patient still shows left Trendelenburg due to continued weakness of gluteus medius This Trendelenburg sign will disappear if proper development of hip muscles is accomplished

Fig 112 Front view of child in Group 2 Bilateral congenitally dislocated hips reduced before age three Result excellent

Fig 113 Same child as in Figs 110 aod 111 Back view of child in Group 2 Bilateral congenital dislocation of hips reduced before the child was aged three Result excellent

siogle or double congenital dislocation will be difficult and will likely prove to be impossible, but if possible, functioo will be impaired The signs in Group 4 vary to a certaio extent from Groups 1, 2, aod 3 In Group 4, wbetber one or both hips are out, there is always a limp wbich is characteristic The Trendelenburg sign is always positive

lateral and bilateral dislocations, tbe greater trochanter or trochanters will be above Nelaton s line In Group 4 the lordosis will io most cases be more marked than in Groups 1, 2, and 3

In Group 4 the symptoms are often very important Io this group fatigue is often complained of, as well as pain Pain and

fatigue in this group increase the older the patient gets It is not to be inferred that pain and fatigue are present in all cases in this group

TREATMENT

In Groups 1, 2, and 3 an effort to reduce the hip or hips should always be made If the reduction is a success, the hip or hips should be put in a plaster spica in a position which is most stable In the majority of cases, the position of maximum stability is one of 90° or more of abduction, with the knee flexed at right angles and the knee or knees posterior to the plane connecting the pubic spine (commonly known as the frog position) If both hips are out, both hips are included in a double spica in the position above described

Before open reduction is considered, at least two attempts at closed reduction should be made If reduction is successful, and the hip or hips are put in a position of maximum stability and allowed to stay in a plaster spica for eight to nine months, and if when the patient is taken out of the plaster spica and allowed to walk it is found that the hip or hips have redislocated, failure must not be admitted A second attempt at reduction should then be made and the same postreduction procedure should again be followed

Treatment in Groups 1, 2, and 3 must be outlined starting from the first reduction and application of the plaster spica to one or both hips After six weeks the single or double spica ought to be bivalved The patient remains in the posterior shell, and a competent physiotherapist teaches the child to develop the adductor muscles in both single and double congenital dislocations The adductor muscles in the reduction of the hip or hips have been given a 'terrible beating by the manipulation and position and first of all need exceptional attention to bring them back to normal The patient with a single or double dislocation ought to be encouraged to walk in plaster after six weeks The bivalved cast can be securely fastened by means of buckles and straps Even in a double spica there is no reason why the patient should not be encouraged to walk It is simply amazing to see how soon these patients learn to walk when tied up in either a single or double

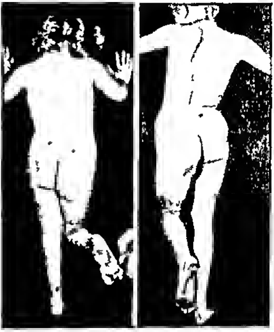


Fig 114 (*Left*) Child under age three Left hip out Picture shows that hip and pelvis on right have dropped—a very positive Trendelenburg sign on right

Fig 115 (*Right*) Congenital dislocation of right hip in a child over age three but under age six Picture shows unusual amount of lordosis for dislocation of a single hip, and there is a definite left Trendelenburg sign Note in some children of this age group that double folds in posterior thigh have disappeared

spica Walking, of course, even in plaster, tends to restore in part the normal mechanics of the hip joint, and when this is restored partially, a gain is made toward final success

After two unsuccessful closed attempts at reduction the question arises as to which is the best course to follow in order to give the patient the best possible function in the

dislocated hip or hips Opinion here varies so much that no surgeon at the present time could possibly give an opinion which would not be subject to criticism First of all, the age in these groups (1, 2, 3) has to be taken into consideration As far back as the early 1920s a Canadian orthopedic surgeon, Dr Herbert P Galloway[8] recommended open reduction by means of surgery of every congenital dislocation of the hip, whether unilateral or bilateral, just as soon as the diagnosis was proven Doctor Galloway was sincere in his belief, and presented certain facts to support it At the present time, in most clinics throughout the world, this viewpoint is not accepted

After two failures to get a satisfactory reduction in Groups 1 2, and 3, what procedure is then to be followed?

The surgeon must consider every angle of each case Such considerations are whether the first and second attempts at reduction of single or double congenital dislocation of the hip are difficult or whether they are easy If at the first reduction there was no difficulty and the head of the femur went into the acetabulum with a definite click or thud, one would have the right to expect with proper after treatment to get an excellent result in function If this definite click or thud of the head into the acetabulum is not obtained at the first effort at reduction the surgeon will probably not get the click and thud at the second attempt Two such failures usually call for more radical procedures The problem is what procedure to follow It is now incumbent upon the surgeon to scrutinize the age of Groups 1, 2 and 3

Group 1 according to most modern considerations, ought to be left alone until the patients reach an age mature enough so that the capital epiphysis of the femur is mature enough to undergo a major operative procedure It seems to be the consensus among orthopedic surgeons that no early surgical procedure is indicated in this group Of course, there can always be an exception to any rule, but the one above stated should seldom be violated When it has to be violated in Group 1, it is usually in patients who have other congenital deformities in connection with hip dislocation, and it is very fair to say that the prognosis in such cases is poor regardless of what procedure is followed

In Group 2, frequently designated as the group ranging from the age of walking up to three years, one must reach the conclusion that surgical interference at this time is not indicated after two unsuccessful closed reductions The above statement will be challenged by many, but conservatism in this group appears to be the opinion of the majority of surgeons dealing with these children

In Group 3, which includes children from the age of three to six after two unsuccessful closed reductions, the author will probably be classified as one who is too conservative, but nevertheless it is his opinion that interference surgically is still not indicated at this time except in rare instances A child between 3 and 6 still does not develop a normal capital femoral epiphysis in unilateral cases or a normal femoral epiphysis on either side in bilateral cases It is true that many surgeons interested in this type of case will contend that to allow patients in this group to continue to walk with one hip or both out of the acetabulum will develop more deformity of all structures than if surgical replacement was done They will also contend that when surgery is finally done late in this group, reduction is very difficult In addition they will hold that such difficult surgery causes more damage to all structures and results in a much poorer end result than does a much earlier resort to reduction by surgery As in all surgical procedures, there has been and probably will be, a difference of opinion on this score The author, nevertheless, feels that cases in Group 3 will have much better function and much less pain if they are not operated upon at this stage, even though

one or two or more attempts at closed reduction have failed

Group 4 This group includes patients from the age of six years on who have had no effort made to reduce single or double dislocated hips that have been out of joint since birth It also includes patients from six years of age and on who have had many unsuccessful closed reductions (Figs 116 117 118) and cases in which open reduction congenital dislocation and all attempts have been failures The attempts at reduction may have been made before the child was 6 years of age

SUBDIVISION B (Figs 121 and 122) Previous operative procedures have been performed

SUBDIVISION C (Figs 119 and 120) Those cases wherein no treatment whatsoever has been attempted

Fig 116

Fig 117

Fig 118

Fig 116 Same child as in Fig 122 X ray showing bilateral congenital dislocation of hips which were reduced when patient was young and which redislocated Parents neglected child for years

Fig 117 Same patient as in Fig 103 Hips reduced Notice malformation of head of left femur

Fig 118 Left hip redislocated Note shoal acetabulum Same patient as in Fig 103 This shows that failure in some cases is always to be expected

by means of surgery has failed in one or both hips The surgeon has a difficult problem if the patient presents single or double congenital dislocation past the age of six when no attempt has been made at reduction of one or both hips He can be well assured that he must divide Group 4 as follows and direct his attention to each subdivision

SUBDIVISION A In this group, from the age of six and on one or more attempts have been made to reduce a single or double

It is next to impossible to describe all the operations to be found in the literature designed to meet the emergencies as described in Subdivisions A B, and C, the subdivisions of Group 4 Certain procedures are available to the surgeon Just what procedure to follow has to be decided by the individual surgeon depending in part upon that surgeon s experience Even though a surgeon has had extensive experience, the decision in this group is very difficult to make

Fig 119

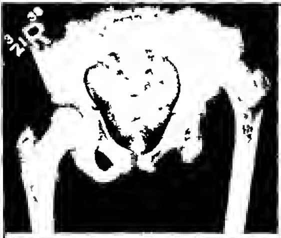


Fig 121

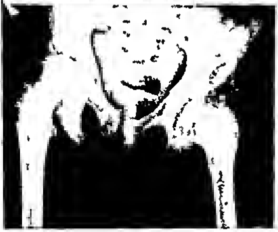


Fig 120

Fig 122

Fig 119 X-ray of child in Group 4 Age 11+ No attempted reduction Reduction accomplished after hip had been pulled down by Roger Anderson well leg splint

Fig 120 X ray of child in Group 4 Age 11+ four years after reduction Hip was originally pulled down by Roger Anderson well leg traction splint

Fig 121 X ray showing bilateral congenital dislocation of hips which have been reduced Shows a bad end result, irregularity of one femoral head and a disappearance of the other

Fig 122 X ray of congenital dislocation of left hip which has been reduced Something has happened to produce a flat femoral epiphysis Note right capital femoral hip appears to be not normal

Treatment in the subdivisions of Group 4 presents a common problem except in Subdivision B A and C have had no open operative procedure Subdivision B has had open surgery but no appreciable improvement and as a matter of fact may have been made much worse Group 4 and its subdivisions offer to the surgeon a very bad prognosis

In all probability Subdivision B of Group 4 has had one two or perhaps more closed reductions before the age of six Following these unsuccessful closed reductions an attempt probably has been made at open reduction and has failed Perhaps a second open reduction has been attempted traction in one form or another having been previously used to pull the hip down with the head opposite the acetabulum At this second open reduction the operator may have decided that the acetabulum was too shallow and that a shelf ought to be built on the anterior superior and posterior margin of the acetabulum He has proceeded to do this but the end result is not good Subdivision B of Group 4 must be considered as a group in which to get a good result is tremendously difficult if not impossible The reasons for this may be varied It may be that there have been impossible anatomic obstacles from the start or perhaps the original judgment of the operator has been at fault, or it may be that the after care of *the patient was not adequately or satisfactorily carried out After such* a bad result it is often easier to determine the cause than it was at the beginning for it will be found that hindsight is better than forethought in most instances

Subdivision A of Group 4 presents a difficult problem Closed reduction has been made one or more times with failure Attempts have been made before the child was six but if the hip or hips are out of the acetabulum after six the patient automatically falls into Group 4 Subdivision A Treatment in Group 4 Subdivision A can be outlined as follows

1 It may be considered useless to attempt another closed reduction

2 Traction of any recognized type r be used to bring the hip down opp te th acetabulum When this is accompl he l n attempt at open reduction may b a le Experience has demonstrated that a geon should never attempt a simultaneou open reduction of bilateral congen tal l located hips Shock and loss of the pat ent quite likely will result One side at a t n e should be done

3 Traction may be used to get the hea l opposite the acetabulum followed by open reduction plus the building of a shelf over the anterior superior and posterior margins of the acetabulum Only one hip at a time should be done

4 Fusion of one or both hips in correct position Certainly both hips ought never to be fused However the author believes that if all procedures have been a failure in a single congenital dislocated hip and the patient has marked limitation of motion and constant pain a fusion of the hip in a corrected position is the procedure of choice

TREATMENT IN SUBDIVISION C No treatment whatsoever has been given or attempted in this group Much consideration and thought has to be used in deciding on what to do in these cases The possible procedures in treatment are numerous Before mentioning them all it seems well worth *while to speak of the treatment* that was used during and possibly before the time of Bradford Lovett and Soutter Bradford and also FitzSimmons a much younger man than Bradford both devised very powerful and complicated instruments for the reduction of the congenital dislocated hip They both accomplished reduction of many hips in this group The report of Soutter and Lovett referred to above undoubtedly contained cases of this group reduced by these machines but whether the bad results reported by them were related to the forceful machine reduction cannot be determined.

Fig 123

Fig 125

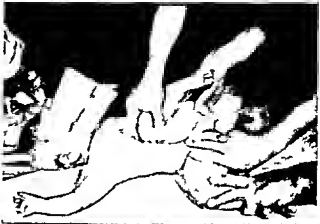


Fig 124

Fig 126

Fig 123 Denuce method of reduction first procedure Massaging adductors of left leg to obtain relaxation Assistant holds pelvis down on right

Fig 124 Denuce method of reduction second procedure Forcing left knee toward right axilla Assistant steadies pelvis

Fig 125 Denuce method of reduction third procedure Forcing knee to table, pushing down with right hand on knee, and left hand under greater trochanter pushing up

Fig 126 Denuce method of reduction fourth procedure By pushing down on left knee with right hand and pushing up with hand on trochanter and by means of circum duction, hip is pushed over rim of acetabulum into socket

The following methods of treatment are at our command in treating cases in Subdivision C

1 No effort is made at reduction either closed or open There is no doubt that the majority of orthopedic surgeons in the United States and Canada would call such a decision ridiculous and the surgeon making such a decision would be classified as a defeatist Regardless of this fact there are certain cases in this subdivision which will be much more happy and comfortable throughout life if the hip or hips are allowed to stay out of joint The decision in this kind of case ought not to be made by one who has not had a large experience in treating congenital dislocations of one or both hips It is the opinion of the author that in the case of a patient in this subdivision over 12 years of age no effort should be made by any method to reduce a single or double congenital dislocation of the hip or hips

2 Another form of treatment consists of putting the dislocated hip or hips in traction One may use any form of traction which has enough force to actually bring the capital femoral epiphysis to a level with the acetabulum If the traction as chosen by the surgeon accomplishes the above result open reduction can then be attempted If often reduction is accomplished and the correct after treatment is followed but it is found that the result is a failure what next? A second open reduction after traction is not advisable

3 Effective traction to pull down the capital femoral epiphysis or epiphyses is instituted and if the desired result is obtained open reduction is done and a shelf is built over the anterior posterior, and superior portions of the acetabulum It stands to reason that such an operation should never be performed on both hips at the same time

4 In the case of a single dislocation where the efforts described under 2 and 3 have failed fusion of the hip seems worth consideration Fusion of a single hip after it has been brought down by traction and openly reduced ought to be considered in those cases which limp have limitation of motion and—much more important constant pain during locomotion Both hips are never to be fused This is a positive statement though such a positive statement may often be a mistake

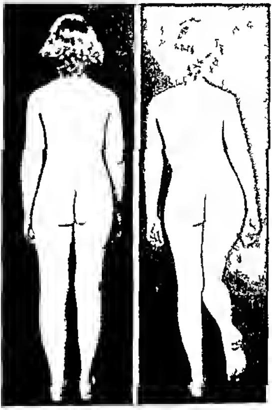
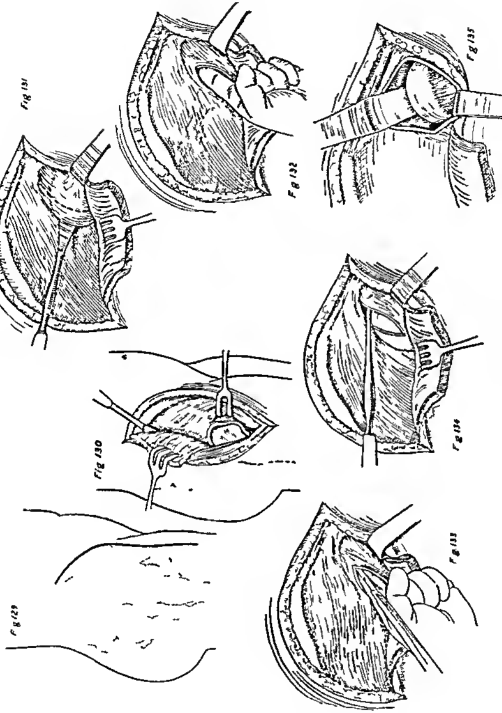


FIG 127 (*Left*) Girl with excellent contour of body Left hip originally out Hip reduced several years ago

FIG 128 (*Right*) Trendelenburg negative

No effort will be made to describe all the methods of closed reduction of the congenitally dislocated hip Instead a single reliable method will be presented

There is a method for the closed reduction of hip or hips dislocated at birth which if understood and executed correctly will be sufficient in all cases amenable to closed reduction This method is that known as the



Figs 129-135 For legends see p 115

Denuce method There seems to be no need of mentioning other methods

The following quotation is from an article on the Denuce technic by the late Dr Z B Adams, of Boston[9]

The reductions are all done manually by Professor Denuce s very ingenious method It is not very unlike the method of Dr John Ridlon but it is not the same as the reduction is preceded by a manual stretching of the adductor muscles and of this Dr Ridlon does not approve

This stretching [Fig 123] is done by gentle stroking of the adductors with the soft part of the palm of the operator s hand—beginning at the pelvis and stroking downward in the longitudinal axis of the thigh the skin having been covered with powder I may say here that in Professor Denuce s reduction and treatment he lays great stress upon the point that no violence or force is to be used As the adductors are stretched the thigh is brought up to right angle flexion and full abduction Having stretched the adductors so that the thigh will lie upon the table at right angles with the trunk—the patient in the decubitus position—the attempt at reduction is then made [Fig 124] This is done by the operator standing on the side of the patient on which is the dislocated hip to be reduced the thigh is flexed on the trunk the knee being carried across in the direction of the axilla of the opposite side and the thigh firmly pressed down on the anterior body wall The knee is held in this position a slight push being made in the longitudinal axis of the thigh The fingers of the operator s other hand are placed under and around the head neck and trochanter lifting up and pressing the muscles in between the head and side of the pelvis then circumduction is begun [Fig 125] The knee is carried across the body trunk to its own side and then downward to the surface of the table and then abducted—all of this time the fingers behind the head are held firmly in place and lifting the circumduction is slowly continued until the thigh is brought to a right angle with the body trunk and lying on the surface of the table the assistant holding down the opposite side of the pelvis by a hand over the crest and anterior spine [Fig 126] The head is felt to slowly come forward and lodge in the acetabulum As some of the doctors have suggested it oozes in At times the shock is very slight

[Two types of operative reduction for the congenitally dislocated hip are in common use

(1) The Galloway type

(2) The Colonna or Hey Groves type

1 The Galloway type a The approach is via the Smith Petersen type of incision (Figs 129, 130 131)

b The capsule is stripped from the ilium and is incised longitudinally over the head of the femur (Fig 131)

c The index finger is introduced through the capsular opening and the constricted portion of the capsule and the acetabulum located mesially (Fig 132)

d A blunt pointed bistoury is passed along this finger, and the constriction incised until the acetabulum is exposed (Fig 133)

e The acetabulum is cleared of fibrous tissue and fibrocartilage the articular cartilage of the acetabulum being left intact (Fig 134)

f Reduction is accomplished by leverage with a blunt skid or blunt curved chisel (Fig 135)

g The capsule is left open and the wound closed in layers

Kidner has varied this technic by an overlap suturing of the opening made in the capsule in an attempt to add stability to the reduction

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Fig 129 Smith Petersen approach skin incision

Fig 130 Smith Petersen approach subperiosteal exposure Gluteus medius and tensor retracted backward and rectus and sartorius drawn forward

Fig 131 Capsule dissected free and incised

Fig 132 Finger exploration of capsule for constriction

Fig 133 Incision of constriction along exploring finger

Fig. 134 Reaming of fibrous tissue and fibrocartilage from acetabulum

Fig 135 Skidding head into acetabulum

Hey Groves has devised a variation in which the longitudinal capsular incision is sutured horizontally to shorten it, and a nail is hammered through the trochanter into the acetabular rim above the reduced head It is long enough to protrude through the operative wound and is incorporated in a plaster spica and then at a later date pulled out through the plaster when stability seems assured

2 The Colonna or Hey Groves type

a The approach is by an incision starting 4 or 5 cm posterior to the anterior superior iliac spine, passing downward and backward to cross the outer aspect of the femur 5 to 6 cm below the upper end of the greater trochanter This passes behind the tensor fasciae femoris and is in essence like the so-called Watson Jones incision (Fig 136) The gluteus and greater trochanter lie behind and the tensor fasciae femoris rectus femoris and sartorius are in front

b The greater trochanter with its abductor attachments is visualized and the trochanter is sectioned from below upward and turned up (Fig 137)

c The capsule is dissected free and incised across its constricted portion above the head The open end is then closed over the head by interrupted sutures (see Fig 138)

d If the rectus femoris is unduly contracted it is lengthened by a sliding horizontal tenoplasty

e The acetabulum is cleared of fibrous tissue and fibrocartilage preserving the articular cartilage (If it has been impossible to get the femoral head down to the acetabular level a new acetabulum is reamed out of ilium at the proper level)

f The head is reduced with as little violence as possible and the trochanter with the attached abductors is replaced and held by strong sutures (Fig 139)

g The wound is closed in layers

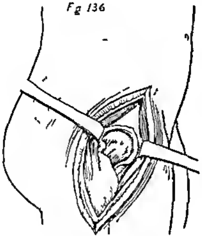
The Hey Groves operation antedating the Colonna, exposes the capsule and frees it from all adhesions The capsule is then severed at the acetabular rim or just proximal to the constriction, if present, and the opening is closed over the femoral head Heavy ligatures are used, and left long after tying A deep and wide acetabulum is created by reaming the articular cartilage being removed if the old acetabulum is used The pelvic aspect of the acetabular floor is exposed by subperiosteal stripping and retraction of the iliacus muscle, and a hole drilled through the acetabular floor The ends of the ligatures closing the capsule about the femoral head are passed through this hole and pulled tight into the pelvis as the head is introduced into the new acetabulum They are then passed through and sutured to the adjacent soft parts This serves to stabilize the joint until the capsular covering of the head becomes adherent to the raw acetabular surface (see Fig 140 p 117)

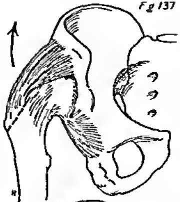
AFTER TREATMENT After any of these methods of open reduction, except the Colonna plaster-spica immobilization in about 30 to 40° of abduction and in good internal rotation is indicated for about eight weeks The spica may then be bivalved, and intermittent exercise slowly and progressively instituted with weight bearing in abduction in the buckled on spica started shortly thereafter

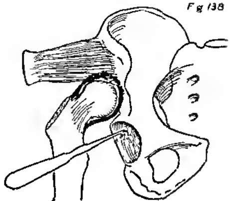
Colonna advises the spica for only four weeks following which it is removed and the hip suspended in abduction The frequent exercise of guarded function is instituted at this time

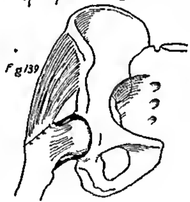
After none of these operations is unsupported weight bearing allowed before the end of three months from the time of operation

All of these operations entail the use of traction as a preliminary in some form with or without tenotomy of the adductors, to get the head down to or near the acetabular level The usual time is about three weeks It may be accomplished sooner, or may take longer Traction should be employed until the time when one is certain that no further









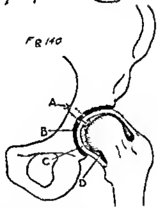


FIG 136 Watson Jones approach gluteus medius retracted backward and tensor fasciae femoris and rectus drawn forward

FIG 137 Line of section and retraction of greater trochanter and attached musculature

FIG 138 Sectioned capsule closed over femoral head, remnants removed from acetabulum and acetabulum re-formed

FIG 139 Capsule-covered head replaced in acetabulum and greater trochanter reattached

FIG 140 Hey Groves *procedure* (A) Ends of capsule suture carried through drill hole and tied on inside of pelvis (B) Bony base of new acetabulum to which outer layer of capsule becomes adherent (C) Capsule, cut across and sutured over head, ends of suture left long and treated as described in (A) (D) The new joint cavity Anchoring of capsule by suture at (A) is to insure stability until outer layer of capsule becomes adherent to acetabulum

lowering of the femoral head can be accomplished by it

The Shelf Operation The technic for this stabilizing procedure, of value when the head cannot be brought down to the acetabular level or when the acetabulum cannot be sufficiently deepened is described in the chapters on anterior poliomyelitis and arthritis Chapters 7 and 15 It should be employed only after preliminary traction as in the open reduction

Anteversion and Its Correction Correction of anteversion in children under three is rarely indicated except in the most extreme cases In later years it is more marked and more frequently has to be treated

TREATMENT After one to three months immobilization in a plaster spica in the internal rotation position a supracondylar osteotomy of the femur is done while the thigh is held internally rotated The leg and the femoral condyles are then rotated to the neutral position and the plaster spica is reapplied Eight weeks postosteotomy immobilization is required for union —Ed]

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5

Acquired and Static Deformities of Lower Extremities

EMIL D W HAUSER, M D

GENU VALGUM

PROPHYLACTIC TREATMENT

Functional Decompensation The principal prophylactic measures consist of recognition and prevention of causative factors Genu valgum often is seen in normal children when they first start to walk, in which case it is a static deformity due to a functional decompensation By functional decompensation is meant an imbalance between the capacity of the structures to do their work and the work demanded of the structures In these young children the structures have not been developed sufficiently to carry out their normal weight bearing With use strength is increased gradually and a spontaneous correction of the deformity occurs The development of the child will vary with the individual I have found that if full correction of the valgus at the knee and ankle has not occurred by the time the child is five years of age, it is well to consider it an abnormality which requires some correction In these cases the genu valgum is associated with a pes valgoplanus which is an expression of a functional decompensation of the foot (Fig 141) Genu valgum also is associated with an external rotation of the leg so that the foot turns out There is a definite valgus of the heel The calcaneus is everted at the subastragaloid articulation Poor posture also is an expression of decompensation and cases of static deformities of the knee are associated with poor posture (Fig 142)

Rickets The most severe genu valgum is due to rickets The treatment of rickets does not come within the scope of this chapter which is confined to static deformities Many static deformities however, may have a rachitic element and for this reason it is always well to carry out antirachitic measures Codliver oil or haliver oil as well as calcium should be prescribed The child should have a normal diet for his age Muscle tone can be improved by means of massage Active exercises are encouraged The child should be exposed gradually to sunshine Muscle tone also is improved from stimulation of the skin by the air blowing on the exposed extremities, as well as by swimming

Factors in Static Genu Valgum In the static genu valgum the imbalance, as already pointed out, is between the capacity and the demand so that the treatment against the etiologic factors would be anything to decrease the load and everything to increase the strength To decrease the load would mean reduction of weight and particularly elimination of prolonged standing Fortunately in small children this is taken care of instinctively, because a child normally will rest as soon as fatigued Ambitious parents who urge their children to

walk before they are ready, or encourage them to walk longer than they should, cause a strain or an increase of the load with resulting static deformity. Occasionally small children, particularly those who are high-strung, are stimulated by exciting play to carry weight-bearing beyond the point of fatigue, and this may be a factor in causing genu valgum. Decrease in have underdeveloped structures, which predispose them to a static deformity—in this case genu valgum. In adolescence, in addition to the factors mentioned, young people sometimes are required to stand on their feet longer than normally, particularly when they are learning a trade. This additional factor in a growing child might be sufficient to bring about a genu valgum.

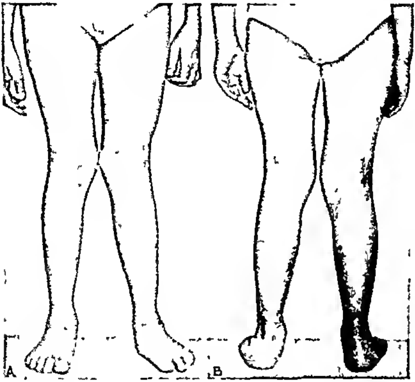


FIG. 141

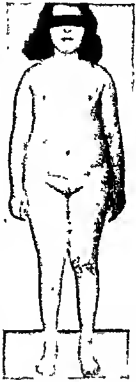


FIG. 142

FIG. 141 Genu valgum associated with pes valgoplanus—an expression of functional decompensation of foot.
FIG. 142 Genu valgum associated with poor posture.

strength as seen in children while they are learning to walk is due to an insufficient development of structures. This may occur at other periods of growth. Growth periods are sporadic in children, and these rapid growth periods result in an insufficient development of structures as compared with the increased amount of work demanded of them. Normal children who have had a severe illness with prolonged bed-rest will Genu valgum sometimes appears in adults. I have seen it develop after pregnancy, in which cases excessive weight was a factor.

The prophylactic measures would, of necessity, take into consideration these factors. In the case of a child who is learning to walk, the instinct of the child is a better guide than the parent or the physician. To prepare for walking, most children go through a stage of creeping. The

length of time required to gain strength and balance varies with each child, and no artificial aids should be used to hurry the process With use, strength is increased gradually and spontaneous correction of the deformity occurs

High strung children should have very definite rest periods preferably one in the middle of the morning and one in the middle of the afternoon In cases of children who are recovering from illness it is better to have more rest periods They could start with a half hour rest period every two hours and later have four rest periods a day As the fatigue disappears the day could be divided in half by having one rest period in the middle of the day The adolescent child who is learning a trade should have periodic rests definitely established for him A rest period at lunchtime, 20 minutes in the morning and again in the afternoon, would in most cases be adequate to prevent the development of a static deformity

During pregnancy *it is important* not to allow the patient to gain excessive weight The increased weight of the child should be taken into consideration, but obstetricians feel that weight beyond normal is neither advantageous nor necessary Periodic rests should be carried out during pregnancy This means avoiding long naps in the afternoon but rather taking rests of 20 minutes to not more than a half hour several times a day, as may be necessary for the individual Between rest periods it is advisable that the pregnant woman carry out a certain amount of exercise, and walking is a practical and valuable exercise when done correctly

Corrective Measures

If the valgus is present after the age of five, correction is indicated In these cases correction of the valgus of the heel will influence the valgus at the knee sufficiently to gain full correction The valgus at the heel is corrected by raising the inner side of the heel of the shoe, as will be seen in the treatment of pes valgoplanus It is my practice to correct the valgus at the knee even though the child is younger than five Simple prophylactic measures which will insure correct growth and not interfere in any way with function should not be denied

Manual Manipulation Some influence in growth can be obtained by molding of

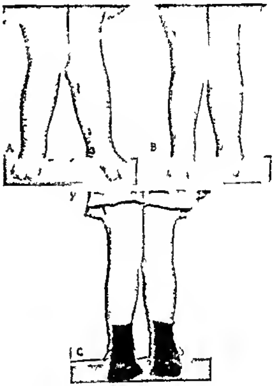


Fig 143 Genu valgum (A) Before wearing corrective shoes, (B) correction of genu valgum (C) standing in corrective shoes

the limbs The patient may be seated on a chair or examination table with the knee fully extended With one hand clasping the knee so that the palm is on the inner side and the other hand placed on the outer side of the ankle, the knee is gently straightened, using the palm of the hand as a fulcrum Force is exerted for a few minutes and then released These movements are repeated five or six times at each treat-

ment and the treatment can be carried out two or three times a day. Gradually the child will tolerate greater force but at no time should there be force exerted to the point of pain. This manipulative type of treatment can be taught to the nurse and to the parents. In addition to its influence on growth the molding has a good psychologic effect on the parents in that they are pleased to be contributing toward the correction.

Corrective Exercise. An excellent exercise for correction by means of active force is walking on the lateral border of the foot clawing the toes with each step. While washing or dressing or even standing at work the foot can be brought into the inverted position and the toes contracted as a corrective exercise.

Altered Statics with Corrective Shoes. The principal treatment consists of improving the mechanics by changing the weight bearing. All static genu valgum is associated with a valgus at the heel and a pronation of the foot with a flattening of the longitudinal arch. By bringing the heel into varus and keeping the anterior part of the foot in normal position the line of weight is brought through the medial side of the knee. Further correction is exerted when the muscles are used to hold the optimum position of posture. This has a tendency to increase the tone of all the muscles of the lower extremities. The improved weight bearing and improved muscle tone as well as the re-establishment of normal action of the muscles influence the growth of the bones according to Wolff's law (Fig. 143). Since there is greater demand on the medial side of the knee and less on the lateral the bones grow straight and the genu valgum disappears. Further correction can be obtained by exercises and games which tend toward overcorrection of the valgus position of the knee. Small children may sit on a keg or on a wide hobbyhorse or they can ride a tricycle or bicycle or ride horseback.

Corrective Braces. Braces have been prescribed for correction. In the past, attempts have been made at correction of the genu valgum deformity by means of night splints and braces. When the knee is flexed direct pressure cannot be exerted to correct the deformity, therefore to obtain a continuous exertion of force it is necessary to use a stiff knee brace. According to Jordan to obtain the maximum amount of leverage it is best to use a bar that reaches from the greater trochanter to the lateral malleolus. An external longitudinal steel bar is used as the correcting force. The bar follows the contour of the lateral aspect of the leg closely fitted to the lower leg in its distal and middle thirds and then it gains some distance from the leg by bridging over the knee in order to allow space for the correction of the knock knee. It regains contact in the proximal half of the thigh. The extremity is held to the longitudinal bar by means of a foot sandal with lacing, a calf band, a thigh band and a pelvic band. The opposing force at the knee joint is introduced by means of a knee cap with a pressure pad over the internal condyle of the femur which pulls the knee toward the lateral longitudinal bar. An elastic material can be used for the knee cap. This gives an active force. The circular bands which hold the lower leg and thigh must be pulled in such a way that they hold the leg in extension. The brace consists of a duralumin band which is made on a plaster model. Such a brace will influence growth in a correct manner, but to be effective the method of treatment offers so many difficulties and so much discomfort that it is much better to carry out a simple osteotomy. Occasionally it is necessary to delay the surgery, during which period a form-fitting brace is worn to prevent the genu valgum from increasing.

Surgical Treatment

A supracondylar osteotomy is done. The contour of the bone usually can be felt and

the site of operation selected solely by palpation, but it is advisable to have x rays which are an additional guide

I prefer the lateral approach (Fig 144) *In this a small longitudinal incision is made* through the skin, a sharp osteotome is in-

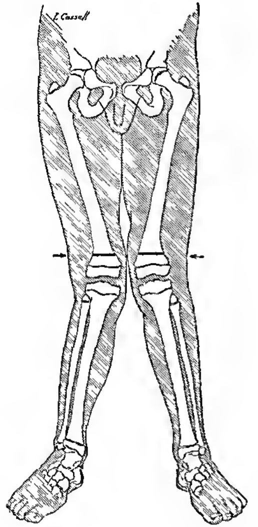


Fig 144 Genu valgum showing site of osteotomy

serted through the incision and forced through the muscle until it comes in contact with the bone It is then turned so that it is at a right angle to the shaft of the bone I use a wide osteotome as it is easier to prevent injury to soft tissues The choice of osteotome will vary according to the size of the bone to be divided *The osteotome* is driven through the bone, partly withdrawn, and moved from side to side to prevent its becoming lodged It is driven transversely through the lateral cortex and partly through the medial cortex Leverage is then placed upon the bone manually so that a greenstick fracture occurs The *position of* fragments can be checked by x ray

The limb is then corrected so that it is straight and the foot is in the midposition with no internal or external rotation This can be accomplished by vision alone A cast is applied from the toes to above the hip Later this cast is removed and a new cast is applied from the ankle to the groin The *first cast is worn for three to six weeks* and the second cast from three to six weeks more, depending upon the age of the patient and how rapidly union occurs The x ray is used to determine the amount of callus and union, and weight bearing is allowed after four to eight weeks, depending upon the firmness of the union (Fig 145)

The operation also can be done through a medial *incision* A small longitudinal incision is made on the medial aspect of the thigh just above the lower femoral epiphysis, and a transverse osteotomy is performed If the deformity is severe it is safer to pass a pair of curved elevators around the lower end of the femur, one on each side This requires a longer incision about 2 to 3 inches in length The medial side of the bone is exposed since the elevators act as retractors A small wedge is removed from the medial half of the cortex A sharp osteotome then is used to divide the bone completely Here again the wide, sharp osteotome is withdrawn from time to time to prevent it from becoming *wedged The flat elevators prevent injury* to the soft tissues The extremity then can be straightened or if desired, in the case of a young child with a possibility of recurrence slight varus position may be obtained The external rotation is corrected and the limb is put in the midposition *neither externally nor internally* rotated

The position is held by a plaster-of paris cast, which goes over both ankle and hip

In the case of a severe deformity a wedge is removed from the anterior medial aspect

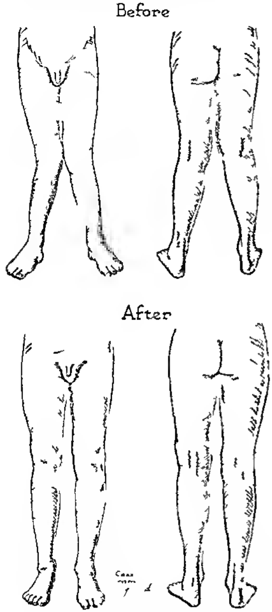


Fig 145 Genu valgum before and after operation

of the bone This wedge is of sufficient dimensions to permit complete correction of the deformity After correction of the deformity an incision is made on the lateral side The wedge of bone previously removed then is inserted in the gap at the lower end of the femur Here also fixation is obtained by means of a plaster-of paris hip spica

Occasionally all of the deformity is in the tibia, in which case the tibia is corrected This is done by a simple or wedge

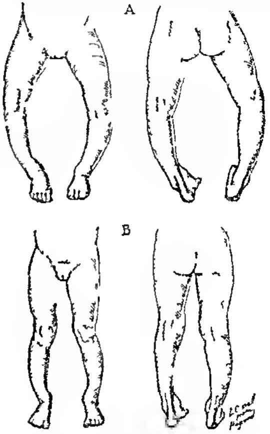


Fig 146 Genu varum (A) Simple round curve, (B) sharp angulation

osteotomy of this bone A few rare cases have been reported in which the correction of the tibia was necessary after correction had been made in the supracondylar area In these cases the femur should be well healed and function re-established before the second operation is performed

GENU VARUM

Causes Most severe cases of genu varum are due to rickets, but it must be remem

bered that even though rickets is the primary cause, weight bearing also plays a role, so that rachitic genu varum has a *static factor* Even though the treatment of rachitic bowleg is the subject of another chapter, there is a static factor, so that the treatment would include not only antirachitic measures but in some cases operative correction of the deformity to improve the static condition or to improve the weight bearing This would also be true for tibia vara Of primary importance would be the correction of the deformity by means of osteoclasis or osteotomy

Conservative Treatment

Manipulation Genu varum develops as a result of poor statics, although much less frequently than does genu valgum The varus condition of the leg usually is associated with external rotation of the tibia and inversion of the foot (Fig 146) Mild degrees of genu varum in children are corrected spontaneously during subsequent growth In these cases the antirachitic measures apparently are of definite value even though rickets is not demonstrable Manual manipulation is of some value To correct the right leg the surgeon stands with his body against the lateral side of the right thigh The right hand grasps the leg at the ankle and the left hand grasps the leg below the knee Force is used to bring the leg laterally, with the left thumb used to give counterpressure over the head of the tibia The force is exerted gradually, no sudden movement is made Sufficient force is used to bring the structures under tension, but not to cause any pain, and the correction is held for half a minute and then released This manipulation is repeated three or four times, and is continued at home by the nurse or the parents

Corrective Braces Corrective braces and night splints, in order to be effective, must reach from the ilium to the heel They are therefore very cumbersome to wear and cause great discomfort, so that even though they have a corrective influence they are not practical

Surgical Correction

Most cases of genu varum respond to the antirachitic measures if they are seen early enough The late cases or the severe cases particularly those in which there is sharp angulation require surgical correction In young children, where the deformity is severe, osteoclasis may be carried out Manual fracture of the soft bones under an

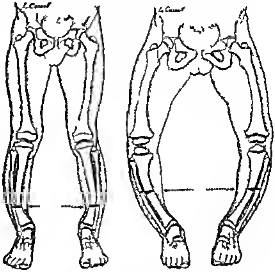


Fig 147 (*Left*) Genu varum with sharp angulation, showing site of operation

Fig 148 (*Right*) Genu varum simple round curve, showing site of operation

esthesia is possible A greenstick fracture occurs and the limb is straightened and fixed with a cast The cast is applied from the toes to above the hip Slight overcorrection may be made and the external rotation can be corrected at the same time The cast is retained for six weeks, after which a brace may be used and a night splint worn for two to four months, depending upon how rapidly solid union occurs If desired, to avoid the use of the brace and night splint, the cast may be worn for a longer period of time After

four to six weeks the patient is allowed to walk wearing the cast, for another four to eight weeks Then the cast is removed

In those patients where there is a very sharp angulation in the lower end of the tibia an osteotomy is necessary (Fig 147) An inch wide osteotome is inserted through a longitudinal incision 1 inch in length It is brought down to the tibia at the most convex point and turned to a right angle with the shaft The osteotome is driven through the tibia until the bone can be easily fractured The tibia is then brought into normal alignment so that the weight bearing line goes through from the middle of the knee to the middle of the ankle

In older children the osteotomy always is preferred In simple round curve deformity the site of the osteotomy is in the middle third of the tibia, and in sharp angulation it is at the height of the convexity (Fig 148) In most cases a simple osteotomy can be carried out Sometimes it is preferable to make a longer incision divide the periosteum pass a curved elevator under each side, and then divide the bone with the osteotome This simplifies the procedure to some degree and makes it a little safer since the elevators protect against injury of the soft tissues and permit a visible safe division of the bone The periosteum need not be closed simple skin closure is sufficient The theoretical objection that the separation of the periosteum from the bone would interfere with healing has not proved true in practice

Another method which can be used successfully according to reports in the literature is that of Brandes It consists of making a simple opening through the skin and passing an electric drill through it The bone is drilled through and then the drill is withdrawn Through the same skin opening another hole is drilled through the bone at a different angle Thus five or six holes are drilled through the bone on the same plane, with the result that the bone can be fractured easily without splintering The correction and alignment then can be made The results as reported by operators who have used this method have been good, and although I have not used it myself, it appeals to me and seems to have considerable merit

In many cases the varus deformity is not only in the tibia but includes the whole lower extremity, so that after the correction of the tibia there is still a bowing which must be corrected by an osteotomy of the femur This should be done after the tibia has healed and walking has been re established A longitudinal incision is made over the lower end of the femur, a distance of about 2½ inches above the knee The incision is carried between the muscles to the bone, exposing about 1½ to 2 inches of the femur A curved elevator is passed around the anterior half In a similar manner a second elevator is passed around the posterior part The handles of the elevators are separated in order that they may act as retractors to give good exposure The osteotomy site then can be chosen A wide osteotome is used the width depending upon the circumference of the bone With a wide osteotome there is less danger of penetrating through soft tissues and the elevators act to protect against the osteotome dividing vessels or nerves The osteotome is driven in for a short distance and retracted and this is repeated until the remaining bone can be easily fractured The leg then is straightened and the wound closed A spica cast is applied from the toes to include the hip

Postoperative Treatment The original cast may be worn for a period of three to six weeks at which time the skin sutures are removed and the second cast applied Gradual weight bearing is started six weeks after the time of operation The cast is removed when solid union has occurred as seen by x ray This usually takes from 8 to 12 weeks

Adult Genu Varum

Conservative Treatment Genu varum is also a static deformity that occurs about the ages of 40 to 50 It is associated with a traumatic type of arthritis of the knee There is an external rotation of the leg, and a pes valgoplanus, and very frequently there are varicosities Correction of the deformity at this period is secondary to correction of the decompensation The treatment consists of the use of Unna paste boots and corrective shoes The re establishment of normal function, increased strength, and decrease of weight with improvement of the metabolism, will bring about a compensation, both of the muscles and of the vessels The correction of the decompensation, taking into consideration the metabolic disturbance as well as the actual statics, will give definite improvement, not only in relieving the symptoms but also in correction of the deformity, which is of secondary significance in this case

Surgical Treatment The bowleg operation in the adult is a serious procedure Most orthopedic surgeons have been consulted by young women who have a relatively small amount of bowing but who are ambitious to succeed on the stage or in the cinema and who desire correction of the deformity The risk is too great in almost every case to justify the procedure Disaster has been met by overzealous surgeons who have attempted to carry out this correction In one instance the deformity was worse than before, in another an infection occurred, in still another gangrene set in resulting in amputation, and there is always the danger of nonunion It is my opinion that surgical correction of the varus deformity in the adult is subject to great risk and should not be undertaken unless all the possibilities have been carefully considered Only if this analysis, after due consideration presents urgent and pressing reasons for the operation can it be held justified

HALLUX VALGUS

Etiology

Hallux valgus is a static deformity and an end result of a functional decompensation of the foot With the decompensation of the foot there is always a valgus of the heel and a pronation in the midtarsal area causing a pes valgoplanus as well as a spread of the anterior part of the foot or pes latus This spread comes about as a result of counterpressure from the floor against the head of the first metatarsal bone The bone is forced upward and outward separating it from the second metatarsal bone, and it also is rotated laterally As a result of the displacement of the head of the first metatarsal bone, the great toe is displaced laterally, giving rise to the hallux valgus

Prophylactic Treatment

The treatment must be based on the mechanical development of this deformity Treatment thus is first directed against the causes of the functional decompensation of the foot, which means that the imbalance between the capacity of the foot for doing its work and the work required of it must be corrected Excessive weight will require a reduction diet Prolonged standing should be interrupted with periodic resting Stiff shanked shoes and arch supports which cause disuse and weakening of structures should be discarded High heels with small weight bearing surfaces which force excessive strain on the anterior part of the foot should be discontinued or limited Pointed shoes, which are a direct influence in bringing about the hallux valgus deformity, are rejected

In addition to the removal of the causes correction of the deformity will be necessary Conservative measures would consist of bringing the heel into varus and the anterior part of the foot into relative pronation, that is, forcing the head of the first

metatarsal bone downward and toward the second metatarsal bone This is accomplished by having a shoe with a sole that is pliable and at the same time strong enough to protect the foot against hard walking surfaces The heel of the shoe is raised on the inner side to bring about a varus position of the foot To re-establish the anterior part of the foot a comma shaped transverse bar is placed on the out side of the shoe, immediately behind the heads of the metatarsal bones Since the head of the fifth metatarsal bone is weight bearing and relatively lower than the second third, and fourth the bar ends under the fourth metatarsal bone The heads of the fourth, third, and second metatarsal bones should be relatively higher than the first and fifth To bring about this relative pronation of the anterior part of the foot, an inclined plane directed in the opposite direction from that on the heel is applied in the comma shaped bar on the outside of the shoe The bar is raised ⅜ inch higher on the outer side than on the inner side, thus forcing the anterior part of the foot into pronation and bringing about a normal position of the head of the first metatarsal bone With the re-establishment of normal position of the head of the first metatarsal bone the great toe tends to return to normal alignment and correction of the hallux valgus is obtained

In cases of children and in mild cases in the adult, correction of the deformity can be accomplished by this treatment In severe cases where the contracture is fixed and the projecting metatarsal head has been irritated to the point where exostoses are present, surgery is required

Conservative Surgical Treatment

Hauser s Technic. My operation consists of a curved incision dorsal to the callus The skin is reflected and the bursa dissected and removed (Fig 149) The abductor hallucis is identified in its displaced plantar position and the tendon is freed The insertion is divided and the muscle is retracted medially Then an incision ¾ inch in length is made on the dorsum of the foot, starting at the interphalangeal space, between the first and second toes The adductor hallucis is identified and brought into view with a curved forceps The insertion then is divided The contracted lateral side of the capsule likewise is divided The great toe is brought over into a varus position The projection of bone that remains at the medial side of the head of the first metatarsal is removed The dorsal and plantar margins are rounded off with a curved chisel The medial capsule then is shortened to hold the toe in the varus position Next, the abductor hallucis is transplanted dorsally and attached to the base of the first phalanx This holds the toe in slight varus position without any external support With the closure of the skin the operation is completed (Fig 150)

It has been my practice never to carry out this reconstruction operation without first accomplishing some correction of the functional decompensation and the pes valgoplanus by means of the corrective shoes Corrective shoes also are worn after the operation They need not be worn at all times Depending upon the foot and the type of work in which the individual is engaged the shoes are worn from two to eight hours a day In the case of women street shoes and dress shoes may be worn when the occasion requires The type of street shoe worn is shown in Fig 151 With men the problem is very much simplified because both street shoes and dress shoes are satisfactory Since using my conservative treatment the percentage of feet in which surgery is required has become very small I have utilized this operation over a period of ten years with excellent results In one case I used silk and the silk suture sloughed out but the tendon attachment held Since then I have gone back to chromic catgut and stay sutures In one of the first cases insufficient correction was taken, as it

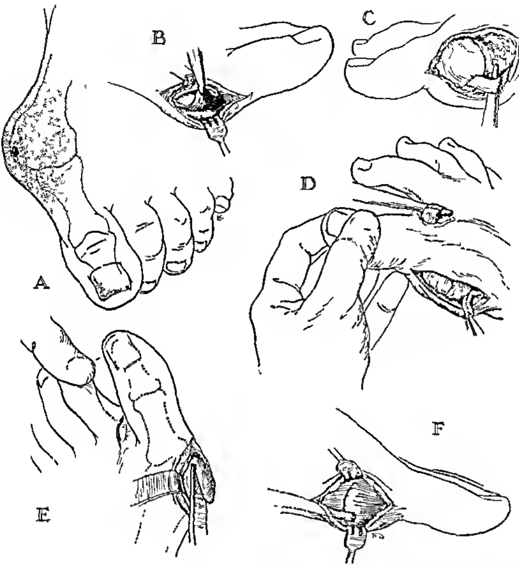


FIG. 149. Author's operation for hallux valgus: (A) Hallux valgus with bursitis, (B) incision and removal of bursa. (C) identification of abductor hallucis, dotted line indicating point of division at its insertion, (D) division of adductor hallucis through second incision, (E) removal of bone with osteotome—*sufficient bone is removed to* permit toe to be brought into varus, (F) closure of capsule and transplantation of abductor hallucis. (Courtesy, Hauser, Emil D. W.: *Diseases of the Foot, Philadelphia,* W. B. Saunders Co.)

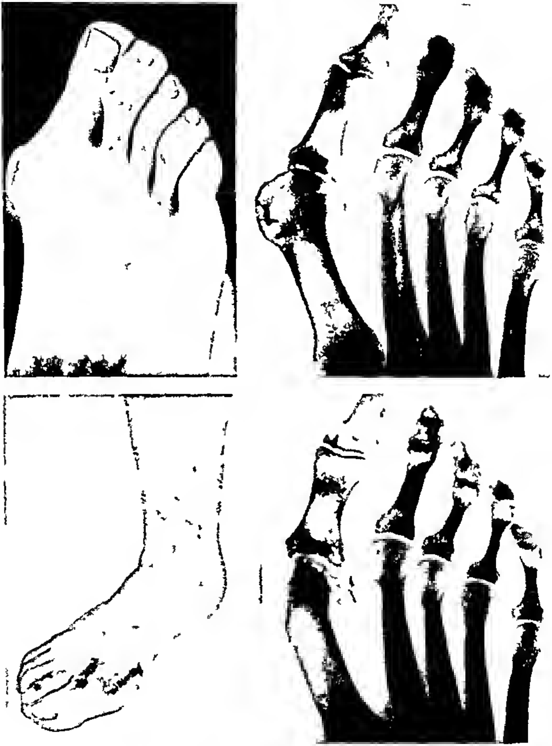


FIG 150 Hallux valgus (*top*) before and (*bottom*) after operation

was rather startling to bring the great toe into extreme abduction, but this position gave an excellent result In one case the contracture was so severe that after the correction there was a subluxation at the metatarsophalangeal articulation Since this gave some limitation of motion and slight pain with dress shoes, the base of the first phalanx of the great toe was resected and an excellent result was obtained In two cases stitch abscesses occurred, but the infection cleared up and the results were excellent Advantages of the operation in addition to the fact that it is logical and a *definite reconstruction type of operation* are that it is less painful after the surgery the convalescent period is short, the foot as a whole is greatly improved and the results are uniformly good The chief drawback is its demand for exact technic

McBride s Technic Another type of operation is that described by McBride The *incision* is begun proximal *to* the interphalangeal joint of the great toe, along the lateral border of the extensor hallucis longus tendon and is extended to a point 1 inch proximal to the metatarsophalangeal joint The dissection is carried deep into the lateral side of the joint The adductor hallucis tendon is isolated and detached at its insertion to the base of the first phalanx and the capsule of the joint opened on the lateral side The lateral sesamoid bone next is dissected out of its bed in the adductor and flexor hallucis tendon The medial skin flap is raised and retracted medially together with the extensor hallucis tendon, thereby exposing the exostosis on the medial side of the metatarsal head The distal end of the first metatarsal then *is approximated* to the second metatarsal The adductor hallucis tendon is attached to the lateral side of the first metatarsal at its neck by means of a suture in the soft tissue and periosteum at that point The soft tissue in this region is fragile and fixation of the tendon frequently is inadequate, in this event a hole is drilled through the neck of the first metatarsal and the tendon is sutured in place with *chronic catgut* The medial capsule is sutured and shortened to maintain overcorrection of the toe After two weeks motion is encouraged Good results have been reported after the use of this method

Lapidus Technic Since the first metatarsal is dorsiflexed and displaced laterally away from the second metatarsal various types of operation have been conceived in which an osteotomy is done of the first metatarsal bringing it down as well as inward, in closer relationship with the second

Fig 151 Street shoe

metatarsal bone The osteotomy was done near the head by Hohman and others have done it near the base Lapidus operates near the base on the medial side and obtains a fusion at the cuneiform at the same time making a correction of the deformity at the metatarsophalangeal articulation

Peabody Technic Peabody has a similar technic, but he removes the wedge closer to the head of the metatarsal bone and also excises the medial side of this bone He places two small drill holes on each side of the osteotomy wedge which is to be removed Chromic catgut is passed through these drill holes to fix the position of the overcorrected metatarsal bone

Keller s Technic The phalanx is disarticulated, and with a Gigli saw a portion of the base of the phalanx is removed, allowing the distal portion to be placed in an overcorrected position medially *without* impinging on the head of the first metatarsal

bone The exostosis is removed in a plane extending obliquely upward and outward in order to preserve the weight bearing surface of the head of the metatarsal bone The remains of the periosteum and the capsule and other soft tissues are brought over the shortened phalanx by a figure 8 suture Figure 8 sutures are used to bring the subcutaneous structures into apposition [The success of the Keller procedure depends in large part on the amount of bone removed At least the proximal third, or, where there has been hallux rigidus the proximal half, of the proximal phalanx should be removed subperiosteally The temporarily flail toe postoperatively stabilizes in a short time Postoperative hallux rigidus is not to be feared after this operation Postoperative tension and pain are minimal —Ed]

Another form of operation is the simple removal of the inflamed bursa since this will give symptomatic relief for some time in a relatively mild type of hallux valgus with bursitis but it does nothing to correct the deformity nor the underlying cause of the deformity The simple removal of the projecting part of the bone also will give some temporary relief and usually is of value only in cases that could be corrected by conservative measures It is not applicable to severe cases and the tendency for recurrence makes it an unsatisfactory operation

Radical Surgical Treatment

Mayo Technic. In the case of complete flatfoot, resection of the head of the first metatarsal bone can be done, bringing about improvement of the condition A curved incision, with its convexity toward the dorsum, is made on the dorsum of the foot over the inner side of the metatarsophalangeal joint The skin is separated from the bursa A U shaped incision now is made through the bursa to form a flap which remains attached to the first phalanx The head of the metatarsal bone then is removed with a bone-cutting forceps The remaining portion of the shaft is made round and smooth The bursal flap then is turned into the joint space and sutured to the lateral capsule of the joint by one or two catgut sutures In this way it prevents an ankylosis The toe is held in slight flexion and abduction by means of a splint The foot is elevated and dressings are kept moist with a 50 per cent alcohol solution. Motion is encouraged after two weeks, and exercises are continued for about three months The original Hueter operation can be carried out, in which case the bursal flap is not utilized

The difficulty with this operation is that the loss of the head of the metatarsal bone shifts more weight bearing onto the others, which means a readjustment of the foot and a painful foot for some months during the time of convalescence Results of this operation thus have contributed to the prevalent belief that the bunion operation is very painful and takes a long time for recovery Furthermore, recurrences do occur and at times contractures are seen An advantage of the operation is its simplicity and the fact that it shortens the head of the first metatarsal bone so that the toe easily can be straightened Many good results have been obtained, but the best results are in the old cases where a complete flatfoot exists, in which case the operation can be performed successfully

DIGITI QUINTI VARUS (TAILOR S BUNION)

The fifth metatarsal bone is displaced from the counterpressure of the floor away from the fourth and dorsally The fifth toe is displaced medially, giving rise to digiti quinti varus The head of the fifth metatarsal bone projects laterally and the friction rub of the shoe in this area causes a bursitis

The technic is similar to the operation for hallux valgus A small curved incision exposes the bursa and the bursa is excised The exostosis is removed with an osteotome

The sharp margins on the dorsum and on the plantar surface are carefully removed The abductor digiti quinti then is dissected and exposed It is brought dorsally and fastened by means of a double 0 (00) chromic suture to the periosteum on the dorsum of the first phalanx This brings the toe into abduction and prevents recurrence of the deformity The skin is closed

HALLUX VARUS

The deformity is either acquired or congenital The acquired cases are very rare and usually are associated with an inversion of the foot It is seen mostly in young children, particularly in those cases where the inversion is a spontaneous overcorrection of pes valgoplanus or flatfoot In these cases correction of the pes valgoplanus obviates the need for the inversion, and the varus position is relieved

Surgical Treatment

In the congenital type there usually is an associated anomaly Frequently there is either an extra toe or part of an extra toe In these cases the extra bone or extra part of the bone is removed and the position of the toe can be corrected either by doing an osteotomy through the first phalanx or by dividing the contracted medial side of the capsule and the tight band of connective tissue in this area The toe then is brought into normal alignment Where an osteotomy is indicated the position is held by means of a plaster of paris cast for eight to 12 weeks, until solid union has occurred Where division of the contracted tissue is carried out a hole may be drilled through the head of the first metatarsal bone and the base of the proximal phalanx A piece of fascia lata is drawn through these holes to form a strong lateral ligament and to hold the toe in the corrected position, after the technic of Sloane This minimizes the chance of loss of position with reformation of capsular contraction

HALLUX RIGIDUS

Conservative Treatment

Acute Phase Hallux rigidus is a loss of motion or limitation of motion in the metatarsophalangeal articulation It usually is due to traumatic arthritis During the acute phase rest is indicated Elevation of the foot with hot packs will relieve the spasm and allow return of motion

Chronic Phase In the chronic phase where there is a loss of joint space and overgrowth of bone conservative treatment may be carried out in the mild cases Relief is obtained by taking the weight off the metatarsophalangeal articulation This can be done by raising the inner side of the heel and also by putting a felt pad inside the shoe just under the longitudinal arch, with an inclined plane directed laterally Some of the weight can be taken off the head of the first metatarsal bone by placing the felt pad directly behind the heads of the metatarsal bones, or by putting a transverse bar on the outer side of the sole of the shoe proximal to the heads of the metatarsal bones

Surgical Treatment

In advanced cases surgical treatment is indicated In certain selected cases where the etiology of the condition can be established and controlled, the exostoses are removed through a dorsolateral incision The capsule is reflected back and with a thin osteotome the exostoses and overgrown margins are excised After closure of the skin, a cast or splint may be applied to the toe The foot is kept at rest until the acute inflammation has subsided, and motion is permitted as soon as there is no pain with movement Where there is some question about the possibility of recurrence, or in advanced cases the best operation is the resection of one half or one third of the proximal part of the first phalanx of the great toe

METATARSALGIA

Metatarsalgia is pain over the heads of the metatarsal bones, usually in the region of the fourth although it may occur over the second and third

Prophylactic Treatment

Since it is due to abnormal pressure, relief can be obtained by taking weight off the heads of the metatarsal bones This can be accomplished by putting a felt pad posterior to the heads of the metatarsal bones or by putting a transverse bar on the outside of the shoe, behind the heads of the metatarsal bones Since the heads of the metatarsal bones receive undue pressure in most cases, with a dorsal displacement of the head of the first metatarsal bone, correction of the relative supination of the anterior part of the foot is indicated This is achieved by means of the comma shaped transverse bar, which is higher under the heads of the fourth, third, and second metatarsal bones than under the first In other words, raising the heads of these metatarsal bones and making the head of the first metatarsal bone relatively lower would not only effect relief of symptoms but also have a curative effect This condition usually occurs in pes valgoplanus, so that correction of the valgus of the heel by raising the inner side of the heel usually is advisable Increased weight bearing on the anterior part of the foot would predispose to excessive pressure on the heads of the metatarsal bones, therefore, the high heel with its small weight bearing surface would be avoided in the case of metatarsalgia Where a high heeled slipper is a social necessity, felt pads posterior to the heads of the middle metatarsal bones are helpful

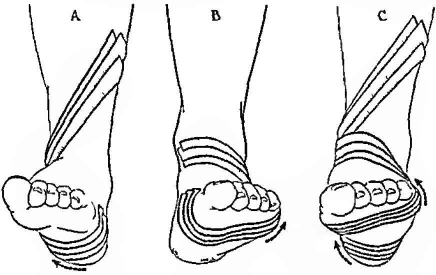


Fig 152 Sketches of foot strapped for foot strain and pes valgoplanus (A) Strapping to bring heel into varus (B) strapping to bring anterior part of foot into pronation, (C) combination of strappings shown in (A) and (B) to bring heel into varus and anterior part of foot into pronation (Courtesy, Hauser, Emil D W Diseases of the Foot, Philadelphia, W B Saunders Co)

Conservative Treatment

Where there is acute inflammation with bursitis and periostitis, weight bearing must be discontinued Rest in bed with elevation of the foot and hot packs usually has a favorable response in three or four days

Then the corrective shoes are worn when the patient starts to walk. At times the pain is acute, but the need for walking is so great that the patient must continue to use the feet. In these cases, bringing the heel into varus with adhesive strapping and the anterior part of the foot into pronation by means of reverse adhesive strapping is indicated (Fig 152)

Surgical Treatment

The pain is due to pressure on the nerve, and the removal of pressure usually will relieve the pain. Cases have been observed in which there was a neurofibroma and in which removal by surgery gave relief. Others have found it necessary to remove the heads of the metatarsal bones in order to relieve the pain. Morton describes a pain in the fourth toe due to pressure on the nerve in the region of the head of the metatarsal bone. The nerve is believed to be impinged between the heads of the metatarsal bones. In the case of an acute attack, removal of the shoe will give relief. The treatment for pes valgoplanus is indicated in this condition, namely, bringing the heel into varus and the anterior part of the foot into pronation by means of the application of an orthopedic heel with an inner raise of ¼ inch and a comma-shaped transverse bar with an outer raise of ⅛ inch to a pliable shoe with a heavy sole, and then re-establishment of normal gait. Division of the nerve has been advised, but in my experience this has been unnecessary. This also applies to injection of the nerve with alcohol

MORTON'S TOE

Morton is of the opinion that when the first metatarsal bone is shorter than the second, abnormal weight bearing will occur, so that there will be an undue pressure on the heads of the lateral metatarsal bones. In my experience, the first metatarsal bone usually is shorter than the second, and this condition has been observed in feet with excellent function. If there is a decompensation and true pressure on the heads of the lateral metatarsal bones, it is true that relief is obtained by raising the inner side of the shoe under the first metatarsal bone, but this encourages an abnormal condition and ultimately will lead to a fixed position of supination of the anterior part of the foot. This is the same objection that is offered against metal arch supports or the so called arch preserver shoes. The metal arch support that is most effective is one that has an inclined plane to bring the heel into varus with a raise behind the heads of the metatarsal bones. If proficiently used such an arch support can be designed and will give relief, although when relief is obtained there is an increased disuse which will lead to further decompensation and ultimately to a dependency upon supports and the condition will become worse. The same principles would apply when there is a hyperflexible first unit. In this condition usually there is a general structural weakness, and in my opinion the increase of the strength throughout, with re-establishment of normal position of the foot, is more valuable than the supportive treatment under the first metatarsal unit

METATARSUS VARUS

Metatarsus varus may be congenital, it may be a residue of an incomplete correction of a clubfoot, or it may be a static deformity. As a matter of fact, the most common metatarsus varus is the static deformity, as seen in children who invert the foot for a spontaneous or instinctive correction of pes valgoplanus

Conservative Treatment

When seen early, correction of the pes valgoplanus by means of the corrective shoe automatically will discontinue the inversion and the metatarsus varus. When seen in older children, where the varus position has been retained for some time, there is an actual bowing of the first metatarsal bone,

as well as of the second and third to a lesser degree In these cases an osteotomy at the base of the first metatarsal bone, with correction of position and retention by means of cast, should be done This is an extremely rare circumstance

CLAW TOE

Etiology

Clawtoe or contracted toes occur as a static condition associated with pes valgoplanus. In the decompensated foot with pronation in the midtarsal area and lowering of the longitudinal arch the plantar fascia and the short plantar muscles of the foot which extend from the calcaneus to the toes are put under tension The distance from the origin and the insertion of the muscles is greater than normal The result is a contracture of the short flexors, bringing about a contracture of the toes The first phalanx is dorsiflexed at the metatarsophalangeal articulation The second phalanx is plantarflexed at the proximal interphalangeal articulation This corresponds to the acquired hammertoe

Treatment

Since the deformity is secondary to pes valgoplanus correction of the pes valgoplanus is indicated In children as well as in mild cases in the older patients this will suffice to obtain full correction of the deformity Where the contracture has been of long standing it usually is associated with a short tendo achillis and equinus deformity of the foot In these cases the use of the corrective shoe must be gradual At first a shoe with a low heel is worn for short periods at a time five to ten minutes several times a day These periods gradually are lengthened until the shoe can be worn with comfort the entire day Then the corrective heel and comma shaped transverse bar are applied to the shoe Again the shoe is worn for only short periods at a time five to ten minutes practicing the normal heel and toe gait This means holding the anterior part of the foot well in the air with the heel on the ground and rolling over the heel, then rolling from the outer side of the foot over the anterior part of the foot until the propulsive force is obtained

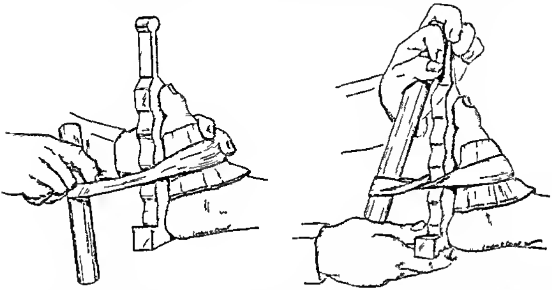


Fig 153 Application of Haglund footboard Loop is screwed down in form of a Spanish windlass Board fastened to foot permits leverage to correct deformity (Courtesy, Hauser, Emil D W Diseases of the Foot, Philadelphia W B Saunders Co)

by means of the great toe The gradual re establishment of the use of the toes not only effects a correction of the deformity, but it prevents recurrence When done gradually and accurately, spectacular re sults frequently are obtained

Surgical Treatment. Where the con tracture is too great to obtain full correc tion by conservative measures, they never to walk, wearing the cast, as soon as the pain subsides Following the use of the cast, corrective shoes are worn until normal func tion has been re established The removal of the heads of the metatarsal bones is de scribed in surgical textbooks although it gives a slight cosmetic improvement, it is mutilating and destructive, and those cases I have observed gave poor functional results

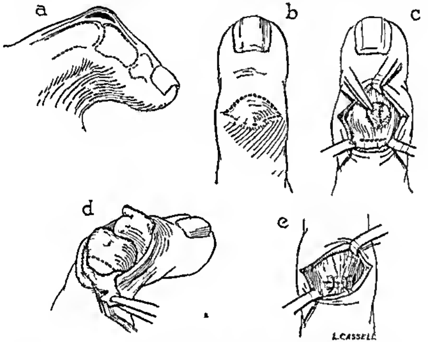


Fig 154 *Author s operation for* hammertoe (a) *Hammertoe with* inflamed bursa and soft tissue contractures, (b) lateral oval in *cision,* (c) *removal of bursa and division of extensor tendon,* (d) re section of head of proximal phalanx, (e) closure with shortening of tendon (Courtesy, Hauser, Emil D W Diseases of the Foot, Phila delphia, W B Saunders Co)

theless should be applied as a preliminary measure as much correction should be ob tained by conservative means as possible Then correction can be obtained by surgery The plantar fascia can be divided as can the contracted tendons of the toes, by means of a tenotomy subcutaneously With the use of the Haglund footboard the deformity can be corrected The force is exerted against the cavus deformity by means of a Spanish windlass (Fig 153) The corrected position is held by a cast The patient is permitted

HAMMERTOE

The fixed hammertoe usually is congenital and occurs most frequently in the second toe The acquired hammertoe would be a long standing deformity of the claw toe type The deformity becomes so fixed that the contracture of the capsule will no longer permit any correction directed against the soft tissue alone

Surgical Treatment

For this type of hammertoe the usual

procedure is to resect the interphalangeal articulation and then bring the toe up into a straight line and allow a fusion in this position. The difficulty with this procedure is that there is almost always a severe contracture at the metatarsophalangeal joint. The toe is stiff and has a tendency to project dorsally so that the tip rubs against the shoe. When the contracture is more severe, the base of the proximal phalanx also may be resected.

Hauser's Technic. Under local anesthesia an elliptical incision is made wide enough to include the painful callus. The small bursa which is present underneath the callus is dissected and removed. The extensor tendon is exposed. A fine forceps is placed underneath the tendon and it is divided at the proximal interphalangeal joint. The articulation is entered and the head of the proximal phalanx is freed. The proximal phalanx is exposed and with a small strong pointed bone forceps the distal end is divided and removed (Fig. 154). The toe is straightened and the divided tendon is sutured and overlapped about ¼ inch. Two fine mattress sutures are sufficient to retain this position.

Conservative Treatment

If for any reason it is inadvisable to make surgical correction, some relief from the discomfort of a hammertoe can be obtained by the application of a felt pad over the dorsum of the first phalanx of the toe. This relieves the pressure and friction rub over the projecting distal end of the phalanx and thus the pain from the corn and bursitis in this area is decreased. The shoe over the projecting part of the toe should be stretched in order to avoid pressure. Surgical treatment is the treatment of choice, but these conservative measures alleviate the symptoms in aged people who do not wish to undergo even this minor operation. It will frequently produce sufficient comfort so that the patient is able to carry out all his functions.

PES CAVUS (HOLLOW FOOT)

Pes cavus usually is congenital or paralytic. At times it is acquired. There is an exaggeration of the height of the normal longitudinal arch. The anterior part of the foot is lowered and the calcaneus is drawn forward. The result is that the foot is in equinus position and the plantar muscles and plantar fascia are shorter than normal. Due to the contracture of the flexor muscles, there is a contracture of the toes.

Conservative Treatment

Since most of these are developmental and the result of high heeled shoes, they can be corrected conservatively. First the shortened tendo achillis is stretched. This is done by wearing low heeled shoes for short periods at a time, five to ten minutes, and bringing the anterior part of the foot into dorsiflexion while walking. Gradually the length of time that the low heeled shoe is worn is increased so that it can worn for a half hour, then a half day, and finally all day. The corrective gait is continued, gradually accentuating the dorsiflexion of the foot. The heel of the shoe either is raised slightly on the outside or is left level. The pressure under the head of the first metatarsal bone as well as under the heads of the other metatarsal bones is relieved by a transverse bar which is placed just posterior to the heads of the metatarsal bones. The transverse bar has the effect of stretching the short plantar muscles, as well as the plantar fascia. With each step the body weight has a tendency to stretch these structures as the foot rolls over the transverse bar.

Surgical Treatment

The conservative method suffices in most cases for the correction of the deformity and relief of the symptoms. This is true also of neglected cases or long-standing cases as seen in adults. Occasionally this type of deformity requires a division of the plantar fascia and division of the

dons of the shortened muscles and then stretching by means of a Spanish windlass This consists of a pad over the dorsum of the foot and a notched footboard A canvas loop is passed over the foot and over the footboard, and a wooden rod is used to wind up the slack of the loop of the canvas thus forcing the arch of the foot down against the footboard (Fig 153) After the correction the foot is put in a cast which goes from the toes to the knee, and as soon as the pain subsides which usually is within 24 to 36 hours, walking can be started A heel is fastened to the cast to simplify walking The cast is worn for a period of six to eight weeks, and then the corrective shoe is worn The removal of a wedge to correct the cavus is not necessary in cases of acquired pes cavus

PES VALGOPLANUS (FLATFOOT)

The most common foot disorder, and one of the most common ailments of civilized people, is the so called *flatfoot*, or pes valgoplanus

Etiology

Characteristic of the condition is the valgus deformity of the heel and the pronation of the midtarsal area which results in a lowering of the longitudinal arch The pronation in the anterior part of the foot is met by counterpressure from the floor This results in a dorsal displacement of the head of the first metatarsal bone and a dorsal displacement of the head of the fifth metatarsal bone which gives a relative lowering of the middle three Since the middle three get more pressure than normal plantar calluses usually occur under the heads of these metatarsal bones The first metatarsal is displaced away from the second, as well as dorsally, and the fifth is displaced away from the fourth as well as dorsally The recognition of these facts establishes the treatment of pes valgoplanus

This is a *static deformity* It always occurs when there is a functional decompensation, which means that there is an imbalance between the load or demand made on the foot and the capacity of the foot to do its work The load may be increased by prolonged standing or it may be increased by excessive weight The capacity may be decreased by strain, by lack of use, and by anything that will decrease the general strength of the individual

Conservative Treatment

Once the deformity exists it is necessary to re establish the foot to normal position but in order to cure the illness it is necessary to remove the functional decompensation The functional decompensation can be relieved temporarily by means of arch supports, plaster of paris cast or in some cases by means of arch supports built in the shoes *This relief is obtained at the expense of use* therefore, there is a tendency to decrease strength and ultimately to increase the functional decompensation This supportive type of treatment may be used to relieve acute strain resulting from a functional decompensation, which is of temporary duration only It also may be used in older people, since relief of the symptoms will be sufficient to allow them to carry out their limited amount of usefulness without pain In most cases, however, it is contraindicated since it interferes with normal use and ultimately decreases the capacity of the foot for doing its work Therefore, treatment should consist of correction of the deformity and re establishment of normal capacity of the foot

To accomplish the correction of the deformity, since the heel is in valgus the inner side of the heel of the shoe is raised to bring the heel into varus The raise varies from $\frac{1}{16}$ inch up to ⅜ inch, according to the amount of deformity as well as the tolerance of the individual In my experience, I have found that the usual raise is about ⅛ inch Since there is a relative supination of the anterior part of the foot that is a dorsal displacement of the head of

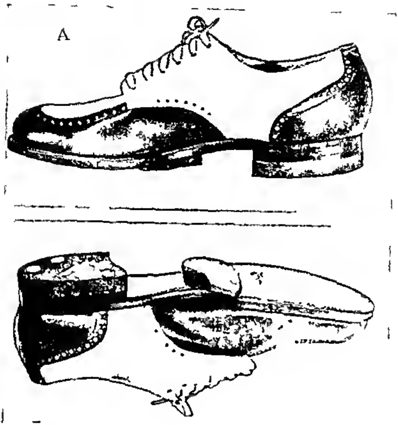
the first metatarsal bone, this should be brought into relative pronation, or the head of the first metatarsal bone should be forced plantarward (Fig 155) To accomplish this a transverse bar on the shoe is utilized This transverse bar has the advantage not only of bringing about the relative pronation, but also of relieving the strain on the heads of the metatarsal bones The bar is comma shaped and lies immediately posterior to the heads of the metatarsal bones Since the fifth metatarsal bone is normally weight bearing and relatively lower than the middle metatarsal bones the transverse bar does not extend under the head of this bone It begins medial to the head of the fifth The inclined plane is directed from the lateral side medially so that the transverse bar is higher on the lateral side The inclined plane is directed from the lateral side medially so that it is at a level plane under the first metatarsal bone The amount of incline varies from 1/8 to 1/4 inch The usual incline, in my experience is 1/4 inch Since the heel is raised on the inner side and the bar on the outer side, there will be a twist in the region of the longitudinal arch Therefore any metal shank that would prevent this twist would have to be removed To make the correction more effective and to act as a preliminary support in the deformed foot, it is advisable to advance the heel of the shoe on the medial side This prevents the pliable sole from being depressed At the same time it aids in bringing the heel into varus Correction of the foot is brought about when weight bearing is placed on these two inclined planes

To increase the capacity of the foot, exercise is necessary The best type of exercise is carrying out normal function—in this case normal gait In normal gait the weight passes from the outer side of the heel, over the outer side of the foot, across the metatarsal area, and then off the great toe With the foot in dorsiflexion, a lever is formed between the leg and the foot This leverage action is used in normal walking The great toe, assisted by the other toes, is used as a propulsive force, just before the foot leaves the ground The result is a rolling gait in which the foot moves in an arc corresponding to the rocker of a rocking chair The patient is instructed in regard to this normal gait The gait is demonstrated and the patient practices walking at home for short periods at a time usually starting with five to ten minute periods five or ten times a day It is well to exaggerate the correction This exaggerated type of gait is used as the practice gait and rapidly influences the patient's gait so that it is brought back to normal

With the re-establishment of normal position and normal function, the pes valgoplanus disappears and the functional decompensation gradually is removed In those cases where fatigue evidently is due to prolonged standing, periodic rests are prescribed This means resting 10 to 20 minutes at intervals during the day If the prolonged standing is interrupted with rest periods, the muscles are given time to recover so that they can carry out their function without strain

WEAK FOOT

Weak foot is a precursor of pes valgoplanus or flatfoot In case of weak foot there is a functional decompensation present so that there is an imbalance between the capacity of the foot to do its work and the work required of the foot Usually with weak foot the disturbance is in the capacity of the foot This may be due to a prolonged illness, rest in bed, improper use, lack of exercise, or the wearing of high heeled or stiff shanked shoes which do not permit normal use of the foot It also may follow an injury In weak foot the functional decompensation exists without the deformity, in other words, there are subjective symptoms without objective findings The arch looks comparatively normal, but there is pain However, weak foot, if not treated



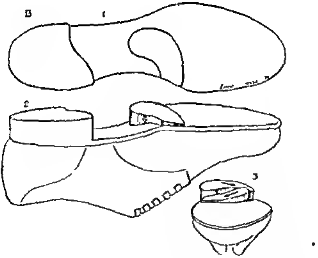


FIG 155 (A) Photographs of corrective shoe for adolescent girl

(B) Sketches to illustrate Hauser bar (1) Plantar aspect, showing shape of bar and its relationship to heel (2 and 3) Pictures *in linear perspective to show relationship of inclined* plane of heel to inclined plane of bar (Courtesy, Hauser, Emil D W Diseases of the Foot, Philadelphia, W B Saunders Co)

ultimately will result in a case of pes valgoplanus

Treatment

The treatment for weak foot, then, is primarily to increase the strength of the foot This would include removing the etiologic factors such as high heels which do not permit normal use, or stiff-shanked shoes which also interfere with the exercise of the foot Since the weak foot tends to bring about the pes valgoplanus deformity it is well to forestall the deformity by means of the corrective shoe Treatment, therefore, would include a pliable soled shoe with the heel raised on the inner side and a comma shaped transverse bar raised on the outer side periodic rest to prevent strain and the re-establishment of normal gait as the best form of exercise Exercises are introduced gradually which means walking in the corrective shoes for short periods at a time starting with five minutes several times a day and increasing the length of time the shoe is used until it can be worn all day Corrective shoes are worn until full strength is re-established

RIGID FLATFOOT

Rigid flatfoot is the result of a neglected pes valgoplanus If the deformed position is allowed to continue for a long period of time, muscles ligaments and bones all adjust themselves to their new positions The result is a fixed pes valgoplanus or rigid flatfoot Continuation of the functional decompensation with the rigid flatfoot present, gives rise to arthritic changes in the joints, thus increasing the rigidity

Treatment

Since the chief complaint is pain, and the pain is due to the functional decompensation, relief of the functional decompensation is indicated This can be accomplished by means of metal arch supports These have the disadvantage that they are very difficult to adjust. Arch supports made of felt are easily shaped to suit the need of the individual The felt is cut to form an inclined plane under the longitudinal arch This inclined plane is directed from the medial side laterally and brings the heel into varus It also brings the pronated midtarsal area into supination by raising the longitudinal arch A transverse pad also is made with an inclined plane directed from the lateral side medially and is placed immediately posterior to the heads of the metatarsal bones but not under the fifth It is higher under the fourth, third, and second metatarsal bones than under the first, thus re-establishing the normal relationship of these metatarsal heads but at the same time relieving the pressure on the depressed metatarsal bones These pads usually relieve the acute symptoms In chosen cases the correction can be carried out further by means of the corrective shoes in which the inner side of the heel is raised and the transverse comma shaped bar is applied to the sole of the shoe and by means of slow re-education of the patient to normal gait In many cases the amount of correction obtained in spite of the fixation and the arthritic changes by roentgenogram, is beyond what one would normally expect

Manipulation Since most of these cases occur in older people the treatment usually is limited to the conservative measures Occasionally a rigid flatfoot may be seen in a younger person in which case manipulation under anesthesia will be indicated Manipulation consists of bringing the heel into varus by means of the Thomas wrench and the anterior part of the foot into pronation by means of a special wrench (Fig 156) Corrected position then is retained in a plaster-of paris cast As soon as the pain subsides walking is permitted either with a walking caliper or with a heel fastened to the cast

Surgical Treatment In rigid flatfoot where conservative correction cannot be carried out, a fusion of the subastragaloid

articulation will give relief In this connection, the calcaneocuboid and talonavicular joints also show arthritic strain and should be fused—so called triple arthrodesis

ACUTE FOOT STRAIN

Acute foot strain usually occurs as a result of sudden exertion The symptoms are pains in the ligaments and in the muscles of the legs

Treatment

Treatment consists of strapping the foot with adhesive The ligamentus strain is relieved when the heel is brought into varus therefore, the foot is held in varus and adhesive tape 1 inch wide is used to hold the position (Fig 152) The strapping starts below the lateral malleolus and runs across the plantar surface of the foot, up the medial side of the leg for about 6 to 8 inches It covers the foot from the posterior part of the heel anteriorly until it reaches below the navicular bone This fixation usually is effective for from five to ten days Occasionally in severe strain it may be necessary to repeat the strapping and keep up the fixation for a period of from 12 to 21 days The symptoms are usually relieved by the strapping, but it should be continued until walking has been re established without pain for a period of at least three or four days

SHOES AND FOOT POSTURE

The treatment of static deformities of the foot and leg has emphasized the importance of normal weight bearing and the carrying out of normal function In normal weight bearing of the lower extremities the body weight is transmitted from the pelvis through the femur, down to the tibia and fibula, then through the talus onto the calcaneus and anteriorly to the rest of the foot When a functional decompensation arises, that is, an imbalance between the capacity of the lower extremity to do its normal work and the work demanded of the lower extremity there is an alteration in the alignment of these bones This alteration in alignment at the knee gives rise to a genu valgum and at the foot to a pes valgo planus Therefore these are the static deformities most commonly encountered

Prolonged standing and interference with normal function are the principal causative factors of a static deformity The primary functions of the lower extremity are weight bearing and locomotion To prevent excessive weight bearing obesity and prolonged standing must be avoided In

Fig 156 Special wrench and two views showing its application for correction of supination of anterior part of foot (Courtesy Hauser Emil D W Diseases of the Foot, Philadelphia, W B Saunders Co)

ordinary life the avoidance of prolonged standing offers the greatest difficulties Many occupations require long standing, and for this reason static deformities have been looked upon as occupational diseases With the improvement of working conditions this offense is offered less frequently to normal statics Fatigue is considered both from the point of view of comfort for the worker and from the point of view of efficiency For this reason, change of posi-

tion is permitted whenever possible in carrying out work. Where impossible, as in the case of the traffic policeman, frequent periods of rest are permitted, which means relief every hour or every two hours. This same principle of periodic rests should be permitted and enforced in all occupations that require continuous standing. Even more important than the increase in load or demand is the offense of interference with normal function. As a protection against the hard surfaces on which we must walk it is necessary to wear shoes. Shoes further protect the feet against sharp objects, against penetrating wounds which could carry infections, and against the cold and wet. Shoes were developed for such protection, but gradually they have been altered so that there has been more and more interference with normal use of the foot. Fashion has been an influence in this. The shoe with the narrow high heel and pointed toe could not have been designed for the comfort of the foot nor with the principal idea of permitting the foot to carry out normal function. The shoe that will permit the greatest use of the foot would be one that would have the least interference with the foot itself. Since the primary purpose of the shoe is to protect against the hard walking surfaces, the leather sole has been well chosen, first, because it has a certain amount of resiliency, second, because it has pliability and third, because it has durability. The shoe should be designed so that it fits well at the heel but has ample room for the anterior part of the foot and space enough to allow normal use of the toes.

Normal Gait

In normal gait the body weight is transmitted from the heel across the outer side of the foot, over the transverse arch and off the great toe. This means that the foot is held at a right angle to the leg with the heel on the ground, thus forming a lever. One arm of the lever is formed by the foot and the other by the leg. As the body weight rolls over the foot a leverage action is utilized, which makes for the minimum amount of effort in bringing about propulsion. In walking in a normal manner the heel and toe of a foot are never on the ground at the same time. An arc is formed on the bottom of the foot so that a rolling type of gait occurs. In order to enable the foot to carry out this type of motion, the body must be held erect. Since functional decompensation causes poor posture in the back, and pes valgoplanus in the feet, these conditions usually occur at the same time. Therefore, correction of the flatfoot almost always includes correction of posture, and vice versa. Poor posture means an increase of the normal curves, that is a rounded dorsal kyphosis and an increased lumbar lordosis. The increase of the curves is due to the sagging of the back. By holding the upright position and enabling the foot to carry out normal gait, posture is corrected. In correcting the curvatures of the spine it is necessary to hold the upright position. To continue to hold it, the flatfoot gait which is a shuffling of the body weight from one foot to the other, must be discontinued, and the normal rolling type of gait relearned. These functional exercises therefore, are of primary importance not only in correcting the foot but also in correcting curvatures of the spine, and as we have seen in the static deformities of the knees, bringing the foot into varus condition also corrects genu valgum. There is thus a definite relationship between the static deformities of the back, the knees and the feet. These deformities must first be corrected to permit re-establishment of normal position, and then the physiologic exercise—namely, correct posture and correct gait—must be carried out until normal capacity has been re-established. As a result, (1) the deformity is eradicated, (2) the functional decompensation is cured, and (3) the symptoms as well as the objective findings disappear.

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6

Surgical Treatment of Scoliosis

WILLIAM H VON LACKUM, M D

Within the past quarter of a century, the scope of scoliosis treatment has been immensely widened by the introduction of the stabilizing operations upon the spine Although originally conceived for use in the arrest of disease and prevention of the gross deformities produced by tuberculosis spine fusion has fulfilled the need for the passive control of the spine essential in the treatment of cases of scoliosis that cannot rehabilitate themselves by voluntary muscle control The necessity for arresting progressive deformity and maintaining the correction gained after the institution of corrective treatment has long been recognized the inability of conservative methods to perform these functions has been amply demonstrated Consequently, for those cases of scoliosis requiring additional treatment beyond conservative means in and surgical treatment are more limited it is our purpose to outline and illustrate very briefly the most essential factors needed to guide one in the complete correction stabilization regime

In addition to, and preliminary to, perfect surgical technic, full attention must be given to the many aspects of the deformity such as the differentiation of the primary from the secondary curve, adequate preoperative correction and the selection of the proper area for fusion These factors in turn, must be coupled with close postoperative observation for possible fusion defects Occasionally, double primary curves exist and must be recognized, and when pain is a presenting symptom its many differential possibilities must be analyzed When each of these considerations is accorded careful attention, spine fusion suc

Paul of Aegina sought to correct the deformity with wooden splints Centuries later, in a similar effort, Pare[20] devised an iron cuirass, and though many such devices were used in the years following, it was not until 1878 that the first appreciable advance was made with the introduction of the plaster jacket applied in extension by Sayre[21] Many pieces of apparatus were later devised utilizing lateral pressure for the correction of the deformity, and in their wake followed forcible redressment by Delore[4] and Calot,[3] an adaptation of the treatment afforded the deformities of tuberculosis at that period, machinery devised by Hoffa,[11, 12] Schede,[25, 26, 27] and many others to afford forcible correction, and finally the extension suspension apparatus of Schanz[22, 23] Traction in some direction was utilized in all of these as the principal method for forcibly correcting the deformity At this time, physical therapy, supplemented by the mechanotherapy largely developed by Schulthess,[24] also found its place in scoliosis treatment In America, the Abbott[2] jacket with its principle of forcible correction of the spine obtained by forward flexion gained widespread attention, but it was found that counterpressure was more likely to deform the ribs than create any appreciable correction in severe deformities In recent years, Galeazzi[9] has devised a derotation machine which, when coupled with the use of plaster jackets, accomplishes slow, forcible correction of the deformity, and though the treatment is severe and prolonged the correction obtained is exceptional Steindler[29] has introduced an innovation in conservative treatment along similar lines of derotation, but without forcible redressment He practices a method of compensating the primary curve by creating a secondary curve of equal intensity and then derotating the vertebrae to decrease the curvature, but, as stated by its originator, this method has proved applicable in selected cases only

In most instances, however, modern orthopedic surgeons supplement conservative therapy of severe or progressive deformities with surgery The first surgical procedure for the relief of scoliosis was introduced by Guerin[10] in 1830 who, in the belief that lateral curvature was produced by muscle contracture, performed numerous myotomies upon the spinal muscle of the concave side of the curve To create a better cosmetic appearance, Hoffa,[11, 12] Lange,[13, 14] Sauerbruch,[28] and, in America Hoke[15] among others practiced rib resections either on the concave side of the curve or bilaterally, but the results obtained were negligible for so formidable a procedure With the advent of the stabilizing bone fusion operations of Hibbs,[17, 18, 19] Albee,[1] and McKenzie Forbes,[7] and those of Lange,[13, 14] who claims precedence for his wiring and celluloid splint methods for the collapse deformities of spinal tuberculosis, new interest was stimulated in scoliosis treatment The Hibbs[18] spine fusion which has proved admirably suited for use in scoliosis, was first utilized as a part of scoliosis treatment in 1914 at the New York Orthopedic Hospital and since the introduction of the Risser wedging jacket[17] in 1927, has been used thereafter in conjunction with it Based on the principle that a curved rod can be more easily straightened by bending than by making traction at both ends, this jacket has proved most effective in gaining maximum correction within a minimum time With the demonstration that spine fusion could adequately stabilize the spine and maintain correction, the pre-existing inability of conservative means to accomplish this, which still remains the principal defect of nonsurgical treatment, was readily overcome

ETIOLOGY AND CLASSIFICATION

Functional scoliosis, one of the two fundamental types of lateral curvature, occurs principally in children of school age

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Within the past quarter of a century the scope of scoliosis treatment has been immensely widened by the introduction of the stabilizing operations upon the spine. Although originally conceived for use in the arrest of disease and prevention of the gross deformities produced by tuberculosis, spine fusion has fulfilled the need for the passive control of the spine essential in the treatment of cases of scoliosis that cannot rehabilitate themselves by voluntary muscle control. The necessity for arresting progressive deformity and maintaining the correction gained after the institution of corrective treatment has long been recognized; the inability of conservative methods to perform these functions has been amply demonstrated. Consequently, for those cases of scoliosis requiring additional treatment beyond conservative means, internal splinting by the use of spine fusion is the only effective procedure. Preceded by correction or correction and compensation, it is applicable in most cases of the progressive or severe deformities observed in children and in a relatively large number of cases with severe deformity and associated fatigue or pain seen in the adolescent and postadolescent stages.

With the objective of prevention of physically evident deformity, the surgical treatment of scoliosis involves something more than the surgical procedure itself, and particularly for the benefit of the orthopedic surgeon whose opportunities for study and surgical treatment are more limited it is our purpose to outline and illustrate very briefly the most essential factors needed to guide one in the complete correction-stabilization regime.

In addition to, and preliminary to, perfect surgical technic, full attention must be given to the many aspects of the deformity, such as the differentiation of the primary from the secondary curve, adequate preoperative correction, and the selection of the proper area for fusion. These factors, in turn, must be coupled with close postoperative observation for possible fusion defects. Occasionally, double primary curves exist and must be recognized, and when pain is a presenting symptom its many differential possibilities must be analyzed. When each of these considerations is accorded careful attention, spine fusion succeeds in the fixation and maintenance of the corrected deformity and assures both a good cosmetic result and the relief or prevention of pain. In addition, it has been well proved that in most instances surgical intervention terminates treatment, whereas observation and an indeterminate amount of physical therapy, corsets, and braces are otherwise necessary throughout life.

HISTORICAL DATA

Scoliosis has been recognized since the earliest days of medicine, for Hippocrates,[14] although he classified it with all spinal diseases, gave the condition its name, and

Paul of Aegina sought to correct the deformity with wooden splints Centuries later, in a similar effort, Pare[20] devised an iron cuirass, and though many such devices were used in the years following, it was not until 1878 that the first appreciable advance was made with the introduction of the plaster jacket applied in extension by Sayre[21] Many pieces of apparatus were later devised utilizing lateral pressure for the correction of the deformity, and in their wake followed forcible redressment by Delore[4] and Calot,[3] an adaptation of the treatment afforded the deformities of tuberculosis at that period, machinery devised by Hoffa[11, 12] Schede,[25, 26, 27] and many others to afford forcible correction, and finally the extension suspension apparatus of Schanz[22, 23] Traction in some direction was utilized in all of these as the principal method for forcibly correcting the deformity At this time, physical therapy, supplemented by the mechanotherapy largely developed by Schultbess,[24] also found its place in scoliosis treatment In America, the Abbott[2] jacket with its principle of forcible correction of the spine obtained by forward flexion gained widespread attention, but it was found that counterpressure was more likely to deform the ribs than create any appreciable correction in severe deformities In recent years, Galeazzi[9] has devised a derotation machine which, when coupled with the use of plaster jackets, accomplishes slow, forcible correction of the deformity, and though the treatment is severe and prolonged the correction obtained is exceptional Steindler[29] has introduced an innovation in conservative treatment along similar lines of derotation, but without forcible redressment He practices a method of compensating the primary curve by creating a secondary curve of equal intensity and then derotating the vertebrae to decrease the curvature, but, as stated by its originator, this method has proved applicable in selected cases only

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ETIOLOGY AND CLASSIFICATION

Functional scoliosis, one of the two fundamental types of lateral curvature, occurs principally in children of school age

This form does not exhibit pathologic changes in the vertebral column, but is caused by both a generalized weakening of the musculature and faulty posture. The condition usually can be voluntarily completely corrected.

Among the cases presenting themselves for treatment of structural scoliosis, approximately 20 per cent can give adequate cause for the deformity. Most commonly noted in this group are curves due to poliomyelitis where asymmetrical paralyses of the spinal and extraspinal, thoracic and thoracopelvic muscles allow the development of lateral curvature. Paralytic curves develop insidiously, sometimes long after the disease has subsided, but unless promptly controlled upon inception they may progress rapidly to great deformity. In these cases inequality in leg lengths and tilts of the pelvis due to abduction contracture influence a pre-existing curve. A small but definite group show, as etiology, congenital abnormalities such as hemivertebrae associated with absence or incomplete segmentation of the vertebral bodies and ribs, torticollis and Sprengel's deformity, either associated with or as a part of the primary cause of the deformity. Neurologic diseases such as Friedreich's ataxia, muscular dystrophy, spastic paraplegia or hysteria may give rise to scoliotic deformity, as may also the consequences of disease such as the collapse of the lung and contracture of the thoracic wall following empyema. In rickets the normal strength of the spine may be so undermined as to allow postural and gravitational stresses to produce lateral curvature.

In fully 80 per cent of the cases encountered, however, no cause for the deformity can be determined. Most probable is the theory that some inherent muscular weakness or skeletal or central nervous system deficiency is the primary factor in the inability of the spine to withstand the normal strains required of it. It is difficult to demonstrate this in a given case.

DIAGNOSIS, SYMPTOMS AND CLINICAL COURSE

Diagnosis. Since the average scoliotic patient does not apply for treatment before some deformity is present, the diagnosis is in most instances self-evident. In very early cases where there are, as yet, no subjective symptoms, evidence of the deformity is a slight elevation of one shoulder, a prominence of the scapula, a lateral fullness of one hip, a prominence of the ribs or an accidental roentgenologic finding. In these early cases it is not the method of diagnosing the condition but that of determining the clinical course that merits attention.

Symptoms. In early childhood and on through adolescence, the existence of deformity is often the only complaint. As progress in the curve proceeds, however, there may appear intermittent periods of ache and fatigue in the deformed area, to either the convex or the concave side, and it is increase in growth and in the degree of curvature that terminates in progressive subjective complaints and unsightly deformity. The onset of subjective symptoms may appear at any time during the early period of the development of the curve and is caused by muscle strain. Upon the cessation of progress of the deformity and in advancing age into the third and fourth decades, the mild symptoms increase and are replaced by a variable amount of chronic fatigue and disabling pain, the later subjective manifestations of muscle strain and progressive degenerative arthritis. During childhood and youth flexibility is usually unimpaired, but occasionally a predisposition to arthritic degeneration and a sedentary life aid in the loss of flexibility at an early age and in advancing years its loss ensues quite rapidly.

When first seen, in an effort to designate an etiology, history of past illness should be obtained and, for the purpose of determining the clinical course of the deformity, an accurate record of the physical

findings (including neurologic examination where necessary), standing and sitting heights, measurements of the lower extremities, and routine laboratory tests should be performed. The natural standing position and the effect of bending the spine in both directions should be inspected to estimate the flexibility of the spinal column, the and cosmetic record of the deformity, but, as shown by Ferguson,[5] photographs and tracings alone are insufficient, as, in well compensated curves to 30°, surface conformation of the thorax may be sufficiently preserved to present no gross objective changes. By regular periods of observation and concomitant roentgen studies at six

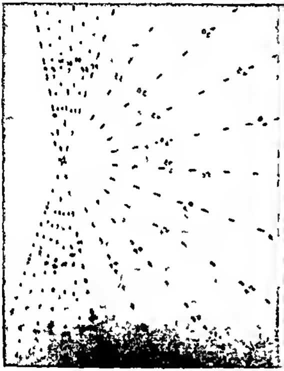


Fig. 157. (*Left*) Protractor, for determination of angle of curve.
Fig. 158. (*Right*) Protractor overlying film and superimposed on dorsal curve. The end vertebrae, indicated by dots, are fifth dorsal and eleventh dorsal, and the apex eighth dorsal. The measurement is seen to be slightly less than 45°.

mobility of the curve itself, and to observe the influence of the curve on the shoulder girdle and pelvis and on the position of the trunk. Roentgen films of the spine, standing and lying, to reveal the relative flexibility of the spine, and lateral bending and pelvic-tilt views to determine, respectively, the thoracic and lumbar spine flexibility and the spontaneous voluntary balance of the sacrospinalis and allied lumbar muscles, should be made. These further rule out or demonstrate developmental anomalies. Photographs should be taken for objective to 12-month intervals, the rate of progress, course, and symptomatic trend of the curve are determined. Spinal flexibility and good posture should be preserved through corrective exercises and surgical interference undertaken should the degree of deformity warrant it.

Roentgenograms made in both the supine and the erect positions on a large film, from the fifth lumbar up, are the only reliable means of recording the deformity; their comparative difference in degree indicates the minimum amount of flexibility. As

stated by Ferguson,[5] the amount of curve shown in the roentgenogram is best expressed by a measurement called the angle of the curve, determined by the use of a protractor (Fig 157) That vertebra at each end of the curve which is nearest to neutral and unrotated is selected as the end vertebra, that vertebra which is most rotated and at the crest of the curve is selected as the apex. In each of these vertebrae the center of the shadow of the body is marked and lines are drawn from the apex to the ends with the protractor placed over the film The angle of the curve is the difference between the resulting angle formed by these two lines and 180° (Fig 158)

Clinical Course Deformity This is exceedingly variable Onset may occur in infancy, childhood, or adolescence, progress may be more or less steady or intermittent, rapid or slow, and the deformity may stop as a mild but stationary curve soon after onset or progress to a severe stage by the time of termination of spine growth Growth studies have been made, however, by Risser and Ferguson,[6] eliminating, in large measure, uncertainty in the natural deforming course of scoliosis They have shown that the increase in curvature stops only upon the cessation of vertebral growth It has been determined that ultimate growth in vertebral height is attained by girls at or before the age of 16 the average age being 14 by boys, at or before the age of 17, the average age being 16 These studies have brought out that the period from six to 12 in boys and six to 11 in girls is a period of comparatively slow growth During this period the curvature is relatively quiescent, while in the succeeding period of rapid growth practically all cases exhibit rapid increase in the development of curvature The exception to this is in paralytic curves where, regardless of age, there is often rapid development with onset of the deformity very early after the acute attack.

Symptoms The natural symptomatic course of curvature of the spine is quite variable and it is doubtful whether any constant, positive criterion is available However, as previously stated, it is believed that the symptom of a rather diffuse, not well localized area of fatigue or ache occurring during or soon after adolescence is definitely of muscle-strain origin, whereas the pain occurring in the third and fourth decades of life, very often associated with well localized areas of tenderness, paraspinal muscle spasm, and roentgen evidence of a thin disk and arthritic lipping is the result of either localized areas of degenerative arthritis somewhere in the spinal column or of decompensation in transitional unstable types of lumbosacral joints (Naturally, extraskeletal or extraspinal symptomatic lesions must be ruled out)

Without entering into a discussion of the mechanical and systemic pathologic factors that may contribute to a progressive degenerative arthritis, it is sufficient to call attention to the additional stresses to which the mechanically unstable lumbosacral joint is subjected when a primary or a compensatory curve causes, in addition, a tilted position of the fifth lumbar body (Fig 159, *right*) on the upper surface of the sacrum Further, the dorsolumbar junction is an area of recognized vulnerability, and each lumbar joint distal to this point carries an added amount of torso weight which combined with the normal lumbar flexibility, permits much shift in vertebral joint relationships These mechanical factors, associated with lateral deviations of the lumbar spine, in which there are further points of added stress at the apex and end vertebrae of the curves, whether primary or secondary, indicate specific anatomic points to which the presence of symptoms should direct attention Combined sacrospinalis muscle spasm and tenderness localized to a single spinous process is often seen to correspond to a roentgen-evident site of localized degenerative change (Fig. 160 A and B) and since these changes in the vertebral bodies and intervertebral disks in adults are often

seen to be disabling symptomatic lesions, observation and conservative treatment in growing children should include roentgen study in films primarily made for an estimate of the progress of the curve, to determine the degenerative course in progress Evidence of advance in these changes, together with mild symptoms even at a comparatively early age, is a factor favoring surgical intervention (Fig 160 C) It is through analysis of this kind that an effective approach is made to the selection of the proper area for fusion in advanced cases with disabling symptoms where surgical intervention without correction is entertained (Fig 159)

In this regard, a primary dorsal curve with a compensatory lumbar curve, usually of lesser degree, is often symptomless, and the compensatory lumbar curve, with its greater motion and weight bearing stresses, having undergone progressive localized degeneration in one or more joints, develops increasingly severe pain The futility of treatment directed to the asymptomatic primary dorsal curve readily can be seen (Fig 160 A and B)

Fig 159 Osteo arthritic degeneration—fusion for pain (*Left*) Primary lumbar curve associated with osteo arthritic lipping and degeneration, with tenderness and pain localized to this single degenerative area, fourth lumbar–fifth lumbar Fusion third lumbar–first sacral without correction completely relieved all symptoms

(*Right*) Incomplete sacralization associated with a tilted position of fifth lumbar body, in same patient

BASIC PATTERNS OF FULLY DEVELOPED CURVES

Primary Curves

In idiopathic scoliosis, and in those cases of paralytic scoliosis in which the imbalance is regarded as confined to the paraspinal muscles and whose behavior, therefore, is believed to be essentially the same, there are several distinct patterns of curves These can be classified by types into the

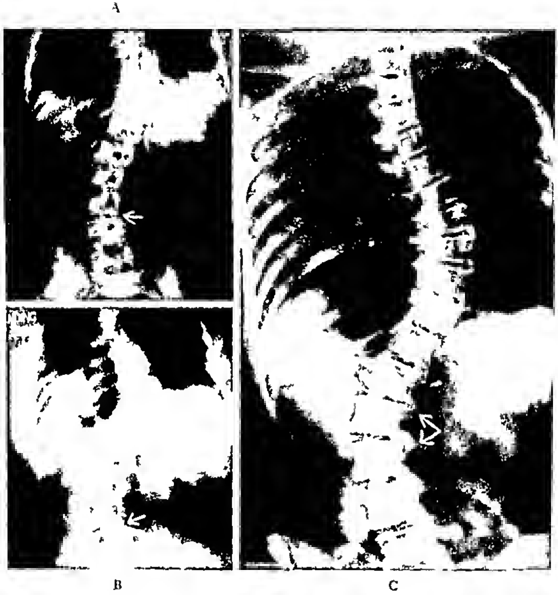


Fig 160 Osteo-arthritic degeneration

(A) Primary right dorsal with secondary left lumbar curve Tenderness and pain at site of third lumbar fourth lumbar

(B) After weight reduction and physical therapy treatment symptoms were relieved Note additional thinning of disk third lumbar–fourth lumbar after a three-year interval

(C) Female aged 15 Slight wedging in bodies of both curves, with concave side slight thinning of intervertebral disks in both dorsal and lumbar curves and definite lipping at apex joints of lumbar curve

three major divisions triple, C shaped and S shaped curves each of which, in its variations, gradually approaches the design of the other A departure from these designs and transitions appears to exist in the more severe paralytic scoliosis where imbalance is assumed to occur additionally in the extraspinal trunk muscles as well as in the paraspinal muscles in this instance there is not only intrinsic instability in the spinal musculature itself, but also an instability of the spine on the sacrum, causing a marked list of the trunk to the right or left

In any etiologic group the basic design of the deformity is usually of multiple curves which tend to balance each other, at times succeeding in this tendency and at other times failing completely to accomplish this purpose These deviations are quite variable in their location and degree and are dependent upon whether, in addition to static effects a single group of muscle imbalance forces is operating on a given segment of the spine, or whether these forces are multiple and affecting more than one portion of the spine

In both the triple and the C shaped types of curve which are much alike, the design of a single primary curve with a compensatory curve above and below is a common pattern of deformity which varies chiefly in the extent to which it may progress Followed through the growth period of the spine, these basic patterns of triple and C shaped curves may, as they develop be gradually transformed into an S shaped pattern of primary curve with compensatory deviations above and below, in which the individual portions of the double curve are asymmetrical in length and degree and accompanied by lateral displacement of the trunk This asymmetry is perhaps caused by the difference in the time of onset in the growth period of the two separate groups of deforming forces but where imbalance factors are acting uniformly in opposite directions a symmetrical type of curve develops, one deviation often complet l n l perfectly balancing the other

In the mild degrees of lateral devi in any of the basic patterns of curves spective of their type and location l balance is essentially undisturbed I l triple or C shaped curves or in the metrical S shaped curve as progre t k place in the deformity demands are for compensatory curves in an atte pt balance the body When these deman l fully met complete balance occurs wh the demands for compensatory curve ar completely unanswered the greatest l formity occurs Intermediate degrees of deformity consistent with the varying degr of response to the demands for compensation occur, but seldom does the curve th t develops in response to the demands for compensation become as great in degree as the primary deforming curve Therefore in the moderate and marked degrees of deformity in the C shaped or triple design of curves each added degree of deformity usually causes greater lateral trunk displacement shoulder or pelvic asymmetry or chest and lumbar muscle asymmetry On the other hand in the symmetrical double or S shaped primary curve, with its short compensatory curves above and below in varying degrees of progress, body balance is well preserved even though the deformity may be quite marked

The extraspinal deformities associated with spinal curves consist chiefly of asymmetry in the shape of the thorax an asym metrical prominence of the lumbar spinal muscles, a difference in the level of the two shoulders a real or apparent difference in the level of the iliac crests, lateral prominence of the hips a right or left tilted position of the pelvis or displacement of the trunk The different basic designs of deformities in their varying degrees of severity, determine not only the extraspinal parts involved but also the degree of the deformity

Compensatory Curves and Decompensation

The spinal column, resting on the sacrum, has the pelvis as a fixed base A deviation of any portion of the spine from its vertical axis whether caused by muscle or central nervous system imbalance factors, instabilities, contractures, or anomalous developments, is met by a spontaneous effort of the unaffected skeletal trunk muscles to maintain the balanced upright position of the trunk Under these conditions the demands for compensation made on any area of the spine adjacent to a primary curve are met by a compensatory response which varies from slight to complete

The compensatory curve or curves, present in response to a demand for body balance exist as (1) Slight curves in the opposite direction, often spoken of as returns to the erect, (2) curves approaching somewhat nearer the degree of deformity present in the primary curve, (3) curves almost equal to the primary curve, or (4) curves greater than the primary curve, where, as Ferguson has described, an unstable lumbosacral joint, because of its instability, may contribute an added factor of imbalance and thereby permit additional lateral curvature

The factors that make compensation possible are (1) A potential compensatory area as great as the area of the primary curve, and (2) actual flexibility in the compensatory area with complete compensatory response

The factors causing decompensation are (1) A primary curve encompassing so great an area that the short area of flexible segments above and below is unable to develop a compensatory curve (2) insufficient flexibility in the compensatory areas, (3) absence in a strong but flexible spine of a normal compensatory response Anticipating normal compensatory response, the degree of deformity in secondary curves is primarily dependent upon the severity of the primary curve, although they are usually slightly less severe unless influenced by other factors such as inequality of leg lengths, congenital anomalies, or an unstable lumbosacral joint

Except where primary deforming factors in the same subject affect both the lumbar spine and the pelvis at the same time, in which instance decompensation is present almost from the onset of a deformity, mild curves in any group of spinal segments are compensated by mild curves above and below in the opposite direction With a normal compensatory response, compensation is maintained during the progress in a primary curve as long as the degree of deformity in the primary curve does not exceed the range of flexibility in the compensatory curve When the primary curve through its progress attains a greater degree of deformity than the secondary curve the comparative lesser range of flexibility in the compensatory curve causes an asymmetry at the extraspinal anatomic site affected, and the decompensation increases in severity in proportion to the relative inequality in the flexibility and the degrees of the primary and secondary curves Where progress in the primary curve is slow and the normally responding compensatory curve has an equal number of vertebral segments lateral balance between the pelvis thorax, shoulder girdle, and head will be maintained even though the symmetry of the posterior thorax and lumber muscle areas has been lost When, however, progress in a primary curve is rapid, or where the number of vertebral segments of essentially equal flexibility available for compensation is less than that of the primary curve, compensation will rapidly be lost

Identification of Primary Curves

Both physical signs and roentgen films are used in this determination Films are made in standing and lying positions, bending views are taken with pressure exerted against both the convexity and concavity of

the curves and views in the sitting position with the pelvis tilted up first on one side, and, in the presence of a double compensatory area, up on the opposite side These comparative measurements of the standing and lying views reveal the minimum comparative flexibility in the primary curve while the bending views reveal the minimum amount of correctibility in the curves The views taken with the pelvis tilted against the convexity of a compensatory dorsolumbar or lumbar curve reveal the capacity for spontaneous balance in the musculature controlling the compensatory curve Although flexibility is great in the young, that portion of the spine affected by demands for compensation exhibits a gradually decreasing flexibility almost from the time of onset This is a response to habitual position, which after long duration, becomes quite marked Usually the identification of the primary curve presents little difficulty, but as Ferguson[31] has pointed out in cases where there is any doubt, certain essential rules can be utilized as follows

1 In the case of three curves, the middle one is usually primary

2 The greater curve or the one toward which the trunk is shifted is the primary curve, except in those cases where the compensatory curve is an overcompensation by *reason of an unstable fifth lumbar vertebra* thus presenting a curve of greater degree than the primary dorsal curve

3 The curve which presents the least comparative amount of flexibility and correctibility is primary The following roentgen study is made to aid in this determination The pelvis is elevated on the side of the convexity of the lumbar curve with the patient in the sitting position If this curve is compensatory it will tend to straighten, but if primary it will remain unchanged The comparative difference is flexibility in the dorsal and lumbar regions of the spine should be kept in mind when utilizing this rule.

The C-shaped primary curve with a compensatory curve of essentially equal degree is, in appearance, not unlike the double S shaped primary curve, the difference being primarily in the greater flexibility in the secondary or compensatory curve The C shaped primary curve, combined with a compensatory curve of long standing in which much adaptive structural change has occurred, through its great loss of flexibility may be quite difficult to differentiate from the S shaped curve in which both curves are primary

PATHOLOGY AND TYPES OF CURVES

General Pathology

The normal erect posture of the spine with its anterior and posterior curves is maintained in perfect balance by both the spinal and extraspinal muscle antagonists of the trunk These different, finely coordinated muscle groups combine to perfect a well balanced support of each individual segment of the spine, maintaining thereby its normal upright position The etiologic factors active in the loss of this fine muscle balance are single or multiple in their areas of attack and in their numerous variations make up the disturbed muscle combinations responsible for the several widely variable anatomic types of curves The specific muscle groups affected their singleness or multiplicity, the extent to which this muscle balance is disturbed and the time in spinal growth when it occurs appear to be the main factors in the determination of the area of deformity, the rate of progress, and the severity finally attained by the curve The two inherent factors constantly associated with structural scoliosis are lateral deviation and rotation, and their effects are seen not only upon the aspects of the vertebral column and thorax but also upon the structure and conformation of the individual vertebrae and thoracic cage With the lateral bend of the column as a whole, the bodies of the vertebrae are rotated to-

ward the convexity of the curve and the spinous processes point in the opposite direction. The strain of the malposition of the vertebral bodies creates gradual change in their appearance so that the vertebra at the apex and the adjacent ones become compressed and are wedge shaped on the concave side of the curve. As the deformity is most marked at the apex of the curve, the vertebrae on either side of the apex are apt to be obliquely shaped while those progressively toward the ends of the curve are apt to retain more nearly normal contours. Within the vertebrae themselves there is also a structural rotation coincident with their outwardly deformed appearance so that the normal trabecular systems appear twisted and spiral shaped in all the involved vertebrae, most markedly so in those at the apex. The intervertebral disks undergo similar compression on the concavity of the curve and the anterior spinal ligaments are thickened while on the convexity they are thinned and fibrous. With severe deformity these ligaments undergo ossification and eventual spontaneous fusion at the apex of the curve occurs.

In the dorsal area the rotated vertebrae carry the ribs with them so that there is backward projection and increased angulation of the ribs on the convex side of the curve and subsequent flattening of the rib curve on the concave side. This deformity of the ribs is primarily a result of the spinal rotation but once deformed and more steeply angulated on the convex side they exert counter pressure upon the vertebrae and so in their turn increase the deforming factors acting upon the spine. In the lumbar area an elevation of the pelvis on the concave side produces abnormal projection of the iliac crest but distortion of the pelvis does not usually occur unless the lower vertebrae and sacrum are involved in the curve.

Throughout the area involving the curve the muscles become atrophic and weak and show signs of fatty degeneration. Because of the deformity of the thorax the lung on the side of the convexity becomes compressed while on the opposite side it may be hypertrophic. The heart is displaced laterally toward the convexity of the curve as are the aorta and, occasionally to a slight degree, the esophagus. Due to abnormal pressure the intestines are crowded low in the abdomen and other organs are frequently displaced or misshapen by the changes evident in the thorax.

Types of Cures and Factors in Treatment

While the thoracic portion of the spine shows a predominance in the incidence of curves to the right, all portions of the spine are subject to deforming forces operating to the right or left or both in the production of structural curvature. Each anatomic portion of the spine presents a different problem in relation to surgical therapy. Usually under consideration because of unsightly appearance, the primary cervicodorsal and upper dorsal deformities as they progress present the difficulty of relative inflexibility due both to fixed deformity of the thoracic cage and in the more severe curves to an inability to force correction for fear of brachial plexus injury from too great traction in the jacket on the upper lever arm of the curve. These factors combine to make surgical intervention indicated early in the spinal deformity as a preventive against the incorrectible secondary thoracic-cage deformities as well as for correction of the curve. The improvement attainable in moderate or severe deformity through correction and compensation is nevertheless usually very worthwhile. Usually under consideration because of thorax and shoulder girdle asymmetry, at times combined with fatigue rather than pain, the primary deformities of the mid and lower thoracic spine similarly, are relatively inflexible and subject to limited correctibility, but have the advantage of a somewhat more effective response to the corrective wedging jacket

Naturally this does not imply that delay in surgical intervention should extend far beyond the stage of moderate deformity. In the primary dorsolumbar and lumbar curves, under surgical consideration because of apparent asymmetry of the iliac crests and lumbar muscle prominence, while the deformity is an important factor, the actual or potential pain because of degenerative changes induced by the static factors acting in the lumbar spine is another very significant consideration. In compensatory low dorsolumbar and lumbar spine curves of moderate or marked degree, the vulnerability and symptomatic features are quite similar. A tilted position of the fifth lumbar body, whether combined with an inherent structural instability at the lumbosacral joint, a spondylolisthesis, or other unstabilizing abnormality, must be recognized and surgery must take care of all these lesions when symptoms warrant.

PRIMARY CERVICODORSAL AND HIGH DORSAL CURVES

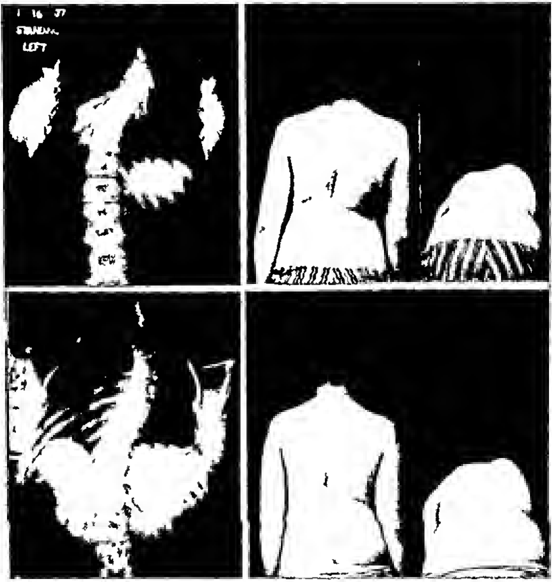
Cervicodorsal and high dorsal curves exist as mild, moderate, and severe deformities and are characterized by convex side elevation of the shoulder and upper ribs, posterior and lateral fullness of the upper chest, and scapular prominence due to posterior rib protrusion. Lateral displacement of the upper thorax varies with the amount of compensatory response in the lower dorsal and dorsolumbar spine. Compensatory curves occur immediately above and below the primary curve and in the opposite direction to it. They range in degree from slight curves to those almost as great as the primary curve (Fig. 161). Because of the relative inflexibility of even the normal thoracic spine, the rapid further loss of flexibility in the presence of structural change, and the relative ineffectiveness of the correction jacket in the higher areas, correction of the primary curve and surgical intervention for fixation of the correction are indicated at a period in the course of their development comparatively earlier than in primary curves in the lower area. The head helmet type of correction jacket, because of the additional head stability it provides, is the most effective corrective implement.

The compensatory cervical, cervicodorsal, low dorsal, and dorsolumbar curves spontaneously correct, when the primary curve is corrected, to the full extent of their flexibility or, if the demands for compensation are less than the full range of compensatory flexibility, proportionally to the amount of correction obtained in the primary curve. This response can be measured in the lateral bend and pelvic tilt films. After completion of jacket correction and fusion of a primary curve, if subsequent corrective exercises have failed to bring about complete reduction of the compensatory curve, it is believed, though not fully proved, that additional correction of this can be obtained by forceful wedging jacket stretching of the soft tissues which have become short on the concave side of the compensatory curves as a result of long continued and habitual position.

PRIMARY DORSAL CURVE

Occurring far more frequently than any other type is the single primary right dorsal curve of idiopathic origin (Figs. 173, 175, 187), involving the central or the lower two thirds of the thoracic portion of the spine. It occurs in varying degrees of severity and the compensatory responses vary from the slight to extreme examples of symmetrical and asymmetrical patterns of S shape and triple curve type. The asymmetry of the thoracic cage, characterized by a posterior protrusion of the ribs on the convex side, scapular prominence, and a concave side recession in the wall of the thorax has, when adequately compensated, almost symmetrical balancing secondary lumbar deformities represented by lumbar spinal muscle prominence and apparent slight iliac crest asymmetry. A variable

A B



C D

FIG. 161 High right dorsal curve—aged 17, idiopathic

(A) Right dorsal curve second dorsal–eighth dorsal apex fifth dorsal is 55°, with a compensatory lumbar curve eighth dorsal–second lumbar of 28°

(B) Preoperative photograph showing upper right trunk displacement

(C) Correction of curve to 42° and fusion seventh cervical to tenth dorsal Because of tendency usually shown in this type of curve to rapid loss of flexibility, early correction and fusion is advocated

(D) Despite the limited amount of correction gained an excellent clinical result was obtained by better alignment and extension of fusion into compensatory areas above and below curve, an alignment through correction and compensation

amount of right lateral trunk displacement with correspondingly less secondary lumbar asymmetry accompanies the lesser degrees of primary curve or those incompletely compensated Surgical treatment should be preventive The tendency is toward rather rapid loss of flexibility, and in the corrective effort in the patient with the full grown thorax the greatest benefits are derived by *balancing lateral* displacement rather than by correcting the posterior rib and scapular prominence In the growing child correction of the curve is followed by some degree of spontaneous restoration of chest symmetry The left dorsal curve of far less frequent occurrence is quite similar in all its features

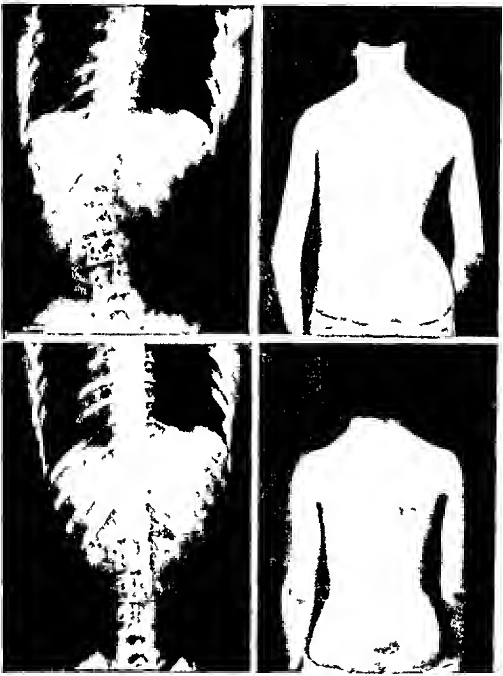
The mild short primary curve in the thoracic area in which only a few vertebrae are involved is often well compensated until the later more severe stages of the deformity at which time it appears as a *U* shaped curve, less well compensated, and often causing considerable lateral displacement of the thorax toward the side of the convexity There is marked and rapid loss of flexibility with extreme rotation and correction is obtained with great difficulty Convex side spinal muscle prominence is evident to various degrees and the iliac crest on the concave side is at times prominent because of the compensatory lateral displacement of the trunk Similar to the situations in the high dorsal curves, fixation of these dorsal deformities, immobilized as they are by the rib cage, occurs early, and early surgical intervention should be practiced as a preventive before any appreciable asymmetry is evident if any considerable period of further growth is to be expected (Fig 162) Irrespective, however, of the degree of the deformity, much benefit can be derived through correction and compensation followed by surgical fixation Similar U shaped imbalance deformities occasionally develop in the low dorsal and lumbar spine

Usually, after jacket correction of the primary dorsal curve in the fairly young patient, the more flexible compensatory lumbar spine spontaneously achieves the maximum amount of correction obtainable This response can be depended upon where the preoperative compensatory curve is slight or moderate, and the deformity consists chiefly of a moderate shift of the trunk to the side of the primary curve Where the compensatory curve is marked and of long duration, only a limited spontaneous correction is possible because of contracture of the concave side soft tissues and at times actual adaptive structural change in the vertebral bodies and intervertebral disks, especially at the apex of the curve Failure to correct the compensatory curve and the primary curve to the same degree is clinically evident in the visible elevation and prominence of the iliac crest on the concave side of the compensatory curve It can be avoided by limited the forced jacket correction of the primary curve to the same amount as that shown to be spontaneously present in the compensatory lumbar curve as seen in the pelvic tilt views Should more correction of the primary curve than this be done, the compensatory curve will remain greater in degree than the corrected primary curve, with consequent prominence of one hip or a shift of the trunk toward the convexity of the primary curve If sufficiently deforming, after long corrective exercise effort, forceful correction of the structurally involved compensatory curve in the wedging jacket and extension of the fusion as in double primary curves may be necessary

PRIMARY DORSOLUMBAR CURVES

While curves in this area may start at the midthoracic spine and occasionally extend to include the fifth lumbar and the sacrum, the curve involving six or seven joints approximately from the eighth dorsal to the fourth lumbar, is most common The apparent elevation of the iliac crest on the

A B



C D

Fig 162 Primary right dorsal curve—aged 14, idiopathic

(A) There is a right curve, fourth dorsal tenth dorsal, apex seventh dorsal, of 41° standing

(B) Note severe decompensation (right lateral trunk displacement)

(C) Correction to 21° and spine fusion fourth dorsal–eleventh dorsal There is incomplete but adequate decompensation of compensatory curve, which is stationary at 30°.

(D) Despite quite incomplete spontaneous reduction of compensatory curve, cosmetic result is excellent

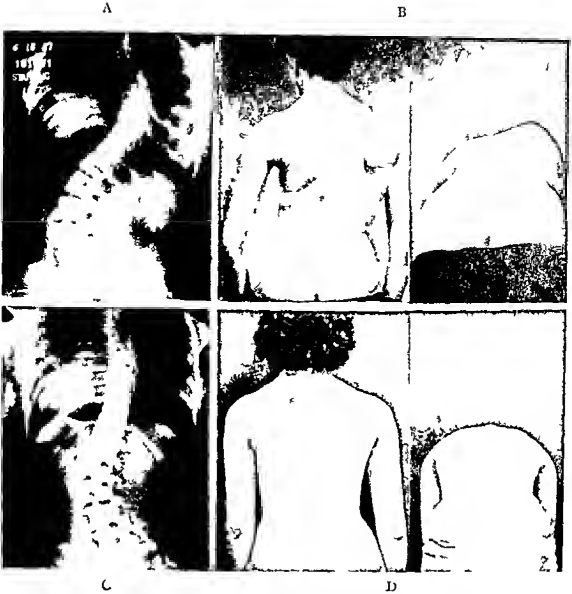


FIG 163 Primary dorsolumbar curve—aged 13, idiopathic
(A) Curve is 30°, seventh dorsal–fourth lumbar, with apex at twelfth dorsal
(B) Prominent hip in left dorsolumbar curve Apparent elevation of hip is a common finding in curves extending low in lumbar area
(C) Postoperative correction to 4° Fusion seventh dorsal fourth lumbar
(D) End result five years later Curve is stationary at 4° and is unnoticeable Cosmetic result is excellent

concave side is the early physical evidence of deformity, followed by convex side dorsolumbar spinal muscle prominence and lateral trunk displacement, each of which increases directly in proportion to the degree of curvature and its excursion downward

The spine above usually returns to the erect, though varying degrees of true compensatory curve with or without evidences of structural change are observed, none of which, as a rule, is sufficiently deforming or potentially symptomatic to warrant concern Below, the fifth, fourth, and third

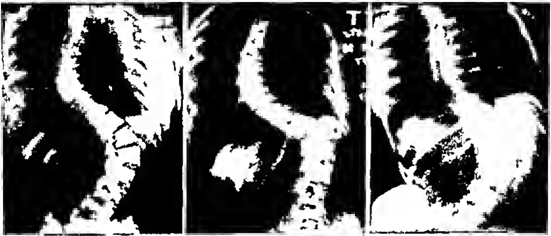
lumbar segments usually have adequate combined flexibility and provide a great amount of compensation The lower the limit of the primary curve, the less proportionally is the compensatory response and the greater correspondingly is the decompensation

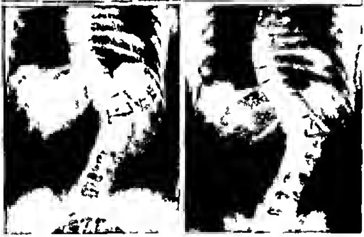
amount of correction and derotation is possible (Fig 163)

PRIMARY LUMBAR CURVES

These are associated with convex side lumbar muscle prominence and usually an apparent lateral fullness and elevation of

A B C





D E

Fig 164 Primary lumbar curve—aged 14 idiopathic

(A) Right curve fifth dorsal-eleventh dorsal apex eighth dorsal to 50° with left curve eleventh dorsal-fifth lumbar, apex second lumbar, 70° Marked tilt of fifth lumbar body on first sacral

(B) Left tilt of pelvis Left curve corrects to 60°

(C) Right bend view Right curve corrects to 30°

(D) Lumbar curve correction to 45° 36 weeks after operation

(E) Area of delayed union twelfth dorsal-first lumbar, terminating in solid fusion, after additional loss of correction, lumbar curve is solidly fused at 55° with trunk balanced

Because of its greater normal flexibility, a better comparative prognosis can be offered in the more severe curves in this area than in the less flexible areas, since a larger

the iliac crest on the concave side The shift of the trunk to the convex side appears early in the development of the curve Tilted fifth lumbar vertebrae, due either to muscle imbalance, to developmental lumbo-

sacral instability, or to developmental tilt of the superior surface of the sacrum, exert a corrective or exaggerating influence on a coincident primary lumbar curve

Just as the primary dorsal curve may have a compensatory lumbar curve which is so slight that it appears as a mere return to the erect in the lumbar spine, so the primary lumbar curve exhibits often a similar response in the dorsal spine in the form of a very mild curve or a return to the erect The compensatory dorsal curve, however, varies greatly and may approach in degree the primary curve It has a much greater tendency, because of its lesser flexibility, to resist the demands for compensation and appear as a curve of definitely lesser degree

Because of the natural flexibility of the lumbar spine, jacket correction of a lumbar primary curve is usually great and attended with an appreciable amount of derotation so that the lumbar muscle prominence is completely or largely overcome The prominence of the iliac crest is, similarly, overcome through the lateral replacement of the displaced lower thorax and subcostal area (Fig 164)

FIFTH LUMBAR TILTS

Tilt of the fifth lumbar vertebra may be the result of an anomalous developmental shape, or of a tilt of the upper surface of the sacrum, or it may exist as part of a primary lumbar or total lumbodorsal curve due to muscular imbalance Because of fifth lumbar imbalance factors, it may also assume a tilted position at the lower end of a compensatory lumbar curve The amount of the tilt and its severity are dependent on the degree of anomalous developmental deformity in the vertebra itself, on the degree of developmental tilt to the upper surface of the sacrum, and on the relative instability present in the different types of structurally unstable lumbosacral joints The various factors involved require careful analysis

Unstable Lumbosacral Joint

1 In Lumbar Curves Secondary to Fifth Lumbar Tilt (Fig 165) Associated *with a laterally* deviated position of the lumbar spine, at times, is a tilted position of the fifth lumbar vertebral body on the level upper surface of the sacrum, in which the pelvis, tilted against the curve, reveals almost full correctibility of the lumbar curve Because of this latter fact, the deviation in the lumbar spine has been regarded as a compensatory curve, secondary to the *lateral tilted unstable fifth lumbar vertebra* The gross deformity is essentially the same as in the primary lumbar curve, though its physical and x ray diagnostic features are those of a secondary curve

Correction is directed toward alignment of the upper surface of the sacrum with the tilted fifth lumbar (occasionally included fourth lumbar) body by means of a jacket applying the corrective force to overcorrect the compensatory lumbar curve When alignment is thus obtained, spinal fusion fifth lumbar to first sacral (fourth lumbar to first sacral where alignment necessitates) is performed and the position is maintained in a wedging jacket support for 12 weeks and occasionally for 16 weeks if the fourth lumbar has been included in the fusion For reasons not understood, the corrected position of the aligned fourth lumbar and fifth lumbar segments is usually not completely retained postoperatively, and consequently a residual lumbar curve of some degree persists The exact *final amount of improvement* through jacket correction and fusion in the type of curve here described is thus somewhat indeterminate, though the procedure is regarded as well worth doing when the symptoms and the severity of the deformity warrant its use Further studies of this type of curve are being made in the expectation of determining a régime that will maintain complete correction and thereby eliminate completely the residual compensatory lumbar curve

lumbar segments usually have adequate combined flexibility and provide a great amount of compensation. The lower the limit of the primary curve, the less proportionally is the compensatory response and the greater correspondingly is the decompensation.

amount of correction and derotation is possible (Fig. 163).

PRIMARY LUMBAR CURVES

These are associated with convex side lumbar muscle prominence and usually an apparent lateral fullness and elevation of

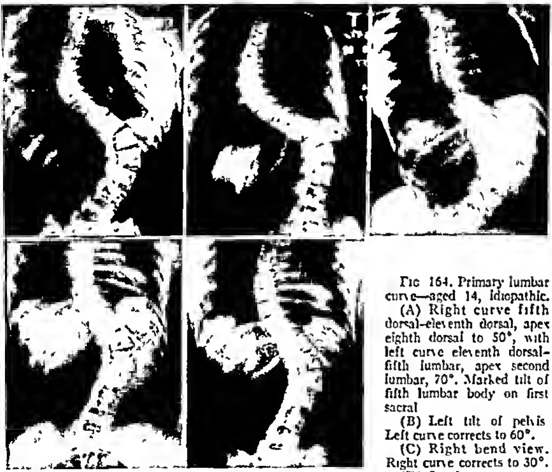


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FIG 164. Primary lumbar curve—aged 14, idiopathic.
(A) Right curve fifth dorsal-eleventh dorsal, apex eighth dorsal to 50°, with left curve eleventh dorsal-fifth lumbar, apex second lumbar, 70°. Marked tilt of fifth lumbar body on first sacral
(B) Left tilt of pelvis Left curve corrects to 60°.
(C) Right bend view. Right curve corrects to 30°.
(D) Lumbar curve correction to 45° 36 weeks after operation
(E) Area of delayed union, twelfth dorsal-first lumbar, terminating in solid fusion, after additional loss of correction; lumbar curve is solidly fused at 55° with trunk balanced.

Because of its greater normal flexibility, a better comparative prognosis can be offered in the more severe curves in this area than in the less flexible areas, since a larger the iliac crest on the concave side. The shift of the trunk to the convex side appears early in the development of the curve. Tilted fifth lumbar vertebrae, due either to muscle imbalance, to developmental lumbo-

sacral instability, or to developmental tilt of the superior surface of the sacrum, exert a corrective or exaggerating influence on a coincident primary lumbar curve

Just as the primary dorsal curve may have a compensatory lumbar curve which is so slight that it appears as a mere return to the erect in the lumbar spine, so the primary lumbar curve exhibits often a similar response in the dorsal spine in the form of a very mild curve or a return to the erect The compensatory dorsal curve however, varies greatly and may approach in degree the primary curve It has a much greater tendency, because of its lesser flexibility, to resist the demands for compensation and appear as a curve of definitely lesser degree

Because of the natural flexibility of the lumbar spine jacket correction of a lumbar primary curve is usually great and attended with an appreciable amount of derotation so that the lumbar muscle prominence is completely or largely overcome The prominence of the iliac crest is, similarly over come through the lateral replacement of the displaced lower thorax and subcostal area (Fig 164)

FIFTH LUMBAR TILTS

Tilt of the fifth lumbar vertebra may be the result of an anomalous developmental shape, or of a tilt of the upper surface of the sacrum, or it may exist as part of a primary lumbar or total lumbodorsal curve due to muscular imbalance Because of fifth lumbar imbalance factors, it may also assume a tilted position at the lower end of a compensatory lumbar curve The amount of the tilt and its severity are dependent on the degree of anomalous developmental deformity in the vertebra itself, on the degree of developmental tilt to the upper surface of the sacrum and on the relative instability present in the different types of structurally unstable lumbosacral joints The various factors involved require careful analysis

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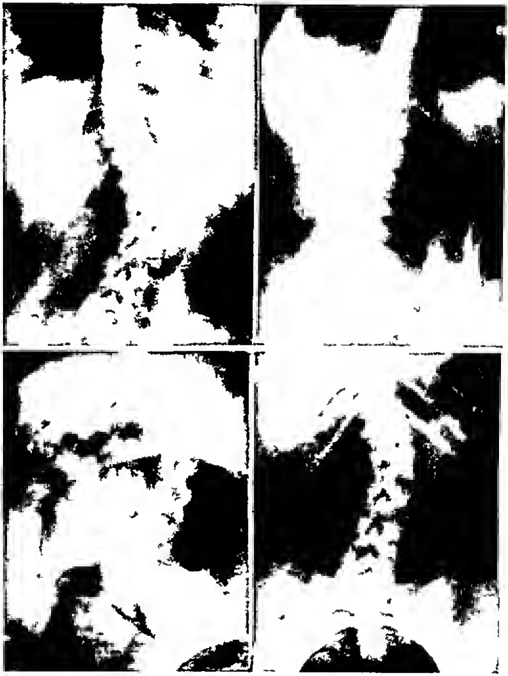


A B C D

FIG 165 Fifth lumbar tilt due to lumbosacral instability

(A) Asymmetrical arch articulations fifth lumbar to sacrum with fifth lumbar body tilted to an angle of 13° on sacrum a compensatory curve is present above eleventh dorsal fourth lumbar apex second lumbar 35°

(B) With left pelvic tilt dorsolumbar deviation corrects fully

(C) Fifth lumbar body aligned on sacrum in a wedging jacket

(D) Postoperative end result Fifth lumbar body tilted 6° Compensatory dorsolumbar curve 22° and pelvic symmetry greatly improved by lateral replacement of displaced thorax A good cosmetic result

2 In Primary Dorsolumbar and Lumbar Curves (Fig 164) The tilted position of the fifth lumbar vertebra accompanying a primary muscle imbalance of the lumbar or lumbodorsal spine varies in direct proportion to the severity of the curve and the degree of intrinsic lumbosacral instability Often because of long duration or growth changes it becomes quite fixed in an extremely oblique position The capacity for compensation is materially decreased by the stability of internal external articulations at the lumbosacral junction and is greatly enhanced by an unstable fifth lumbar vertebra with anteroposterior facets The *curve is characterized by prominence of the* lumbar muscles on the convex side and hip prominence on the concave side of the curve developing early in the deformity and progressing to rather marked degrees in the moderate and severe curves Correction can best be accomplished by bending the jacket in the direction of the lumbar curve aligning the curve as low as the fourth lumbar and following with fusion After this fused area is solid if residual lack of pelvic balance necessitates the spine should be bent in the wedging jacket in the opposite direction to align the lower end of the fusion with the level pelvis This type of curve has been treated in two instances by dividing the wedging jacket transversely at the apex of the curve and manually shifting and tilting the pelvis through the divided section

3 In Secondary Curve Decompensating Because of Instability or the Tilted Position of Fifth Lumbar A compensatory lumbar curve is at times greater than the primary dorsal curve when fifth lumbar instability causes an increase in the deformity A tilted fifth lumbar vertebra with the internal external type of articulation should correct spontaneously in proportion to the amount of correction induced in the primary curve unless influenced by secondary structural changes The anteroposterior and asymmetrical type of articulation with or without spondylolisthesis and with inherent instability in the fifth lumbar vertebra progresses to greater deformity and may necessitate subsequent alignment of the pelvis by wedging jacket to obtain a compensated pelvis and a satisfactory total balance of the trunk Tilt views and fifth lumbar series (anteroposterior lateral and 45°) usually predetermine this need

Wedged or Anomalous Fifth Lumbar Bodies

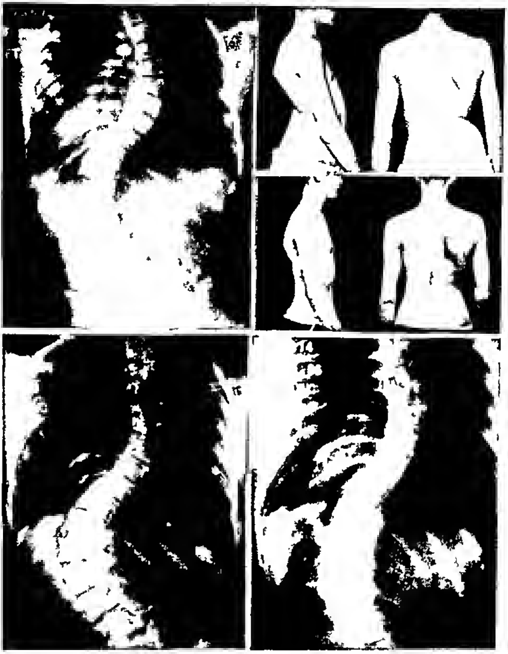
Among the numerous transitional types of lumbosacral joints is the type with the malformed fifth lumbar body (Fig 159 B) *in which the upper surface is developed in* a tilted position to the right or left necessitating a compensatory lumbar deviation and producing objectively lateral trunk shift and apparent elevation and lateral protrusion of the iliac crest and the appearance of a tilted pelvis

As in the frankly unstable and tilted though normal shaped fifth lumbar bodies correction is obtained by exerting a corrective force in the direction of exaggeration of the compensatory lumbar segments thereby aligning the superior surface of the sacrum with the fourth or third lumbar segment Fusion will thereafter maintain the aligned position and the compensatory curve will normally diminish in proportion Body alignment postoperatively is excellent In the third and fourth decades of life fusion without correction for pain due to localized osteo arthritic degeneration is occasionally indicated (Fig 159)

S SHAPED CURVES

Single Primary

At times the vertebral column is affected by a single group of deforming forces producing a single component primary S shaped curve The combination of a single group of deforming forces affecting roughly any portion of the upper or lower half of the dorsolumbar spine with normal com



A B E C D

FIG 166 Asymmetrical double primary curve—aged 12

(A) Preoperatively right dorsal curve fourth dorsal ninth dorsal apex sixth dorsal, is 33° standing Left lumbar curve is ninth dorsal fourth lumbar apex first lumbar, 58° standing Fifth lumbar tilted 15° on first sacral the fifth lumbar instability an additional etiologic factor in dorsolumbar curve

(B) There is moderate trunk asymmetry

(C) Postoperatively, fusion solid third dorsal tenth dorsal 26° Note failure of rigid left lumbar curve to decompensate and an increase of deformity in lower curve to 65° standing

(D) Correction of lumbar curve to 40° and extension of fusion to third lumbar was performed

(Continued on next page)

pensatory response, produces a relatively symmetrical single primary S shaped curve Where compensatory response is appreciably less than the amount in the primary curve, an asymmetrical S shaped curve is present In normal response, where the curve is symmetrical, body balance is essentially undisturbed, while displacement of the trunk or pelvis increases as the severity of the curves increases In differentiating single component from double component primary curves, lateral bending views and pelvic tilt views offer helpful differential findings

In the S shaped curve, where one component of the curve is primary, that component, as shown in bend or tilt views, has a comparatively limited flexibility and correctibility, and is usually slightly greater in degree In addition it usually shows greater vertebral body rotation It may show concave side narrowing of apex area bodies and disks If both are primary, each presents these findings Where one component is compensatory, each of the above features is distinctly less pronounced or absent Structural changes in advancing years, chiefly a decrease in flexibility and correctibility, appear with arthritic changes in both primary and secondary curves and make differentiation in symmetrical curves thereby more difficult

Double Primary

At other times, two separate groups of imbalance factors, operating in opposite directions on adjacent segments of the spine, create a double primary curve In rare instances, triple deforming forces appear active, making a proportional number of primary curves When multiple, the deforming forces may be equal or unequal and opposite in their deforming effect and time of onset The end result is, at times, a symmetrical S shaped curve and, at other times an asymmetrical curve of similar design (Fig 166) The mild symmetrical single and double primary S shaped curve is essentially nondeforming though in the moderate and marked deformities varying degrees of thoracic cage, paraspinal muscle, shoulder girdle and iliac crest asymmetry are evident although little or no trunk displacement occurs The asymmetrical single and double primary S shaped curve is objectively essentially the same as the symmetrical curve except for the inequality in length and degree in the two components of the curve and the addition of varying amount of lateral displacement of the trunk

Symmetrical double primary S shaped curves imply uniform imbalance forces occurring in opposite directions, in which these forces are operating on segments of the spine of essentially equal length, that the time of their onset is the same and that they are equal imbalance stresses, whereas the asymmetrical design of the same curve implies nonuniformity in any one or each of these factors The number of segments of the spine affected by deforming forces, the degree of inequality of these forces, and the duration of growth are the factors that determine the area and design of the curve and its eventual severity The amount of compensatory response varies from slight to almost complete compensation and where muscle power and flexibility are essentially normal and the compensatory curves are equal to or greater than the primary curves,

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(E) Note excellent alignment of trunk

Because of its quite marked disproportionate lesser degree of deformity, the thoracic component of this double primary S shaped curve, initially treated, surgically, may be interpreted as a secondary curve with quite marked structural change Irrespective in Fig 188, the dorso lumbar component of a similar asymmetrical double primary S shaped curve, treated surgically, was followed by no thoracic decompensatory response The good cosmetic result, however, in the latter case, indicates in this type of curve the method of approach most likely to give a satisfactory cosmetic result by a single procedure

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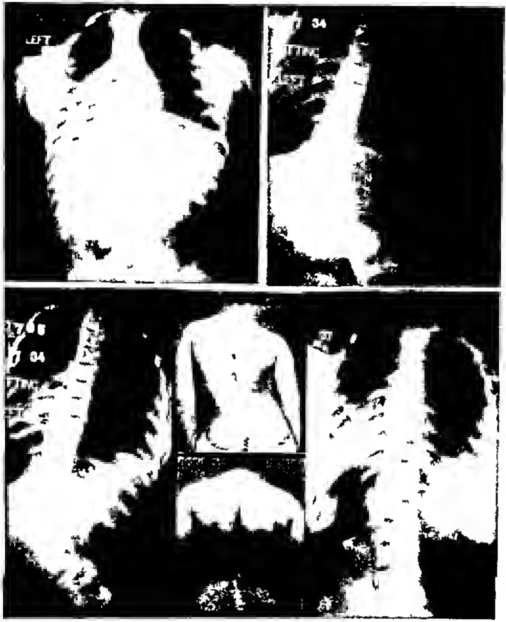

FIG 167 Symmetrical double primary S-shaped curve

(A) Preoperative right curve fourth dorsal tenth dorsal apex seventh dorsal 37° standing Left curve tenth dorsal fifth lumbar apex second lumbar 51° standing

(B) Spine fusion fourth dorsal eleventh dorsal after correction to 0°

(C) Postoperative photograph and film showing residual deformity in distal component of curve

(D) Postoperative photograph and film showing end result after correction and supplementary fusion eleventh dorsal–third lumbar and third lumbar first sacral Inclusion of sacrum was necessitated by low limit of primary lumbar component which would otherwise permit a residual tilt of pelvis

the absence of normal response is controlled by factors not well understood Either component of a double primary symmetrical S shaped curve can be selected for correction and fusion and if the objectively evident end result improvement is not satisfactory, the adjacent segment can be subsequently corrected, aligned, the fusion extended, and the trunk thereby well balanced (Fig 166)

As a rule, however, the part causing the greatest comparative deformity should be treated first in an effort to escape the correction and fusion of the second part, particularly if the deforming effects in the component segment are not too great Where the lower deviation of the double curve is corrected and fused first, its correction and fusion alone brings about a better trunk alignment It assures replacement of the laterally displaced trunk, thus restoring iliac crest symmetry, and removes motion from the greater weight bearing portion of the spine, where degenerative osteo arthritic changes have their earliest onset and greatest symptomatic effect (Fig 167) Through this approach the multiple benefits are quite striking compared to the lesser effect observed in the form of somewhat improved general thorax shoulder girdle symmetry, but relatively unchanged posterior rib and scapular prominence, accomplished by initial correction of the dorsal curve On the other hand, because of its character and position and the natural flexibility of its dorsolumbar or lumbar component, initial correction and fusion of the dorsal curve offers, in addition to alignment of the thorax, the possibility of inducing apparent balance of the apparently unbalanced pelvis and prominent hip through the use of a heel lift without further surgical interference

PARALYTIC CURVES

Because paralytic curves develop insidiously, oftentimes during recumbency and soon after the onset of the disease, all cases of poliomyelitis should be subjected to constant and rigid observation of the spine In the earliest period of their development these curves present much fluctuation in area and direction but as follow up physical examinations and roentgenographic views are made from month to month definite structural deviations become apparent Paralytic curves often progress rapidly, list of the trunk to the right or left is frequent, their length and areas are quite variable, though they appear in most instances as long C shaped curves in wide spread and marked paralysis

When warranted by severity or rapid progress, irrespective of age jacket correction should be applied and fusion performed as in the idiopathic types (Fig 168) In some instances in planning surgery allowance must be made for inequality in leg lengths and atrophy of the buttocks by excluding one or two low lumbar segments from a fusion area, or, where list of the trunk needs stabilization, by permitting a small amount of residual incomplete correction Severe abduction contracture of the hip is an etiologic factor in the production of certain lumbar curves which may be corrected by abductor release Where imbalance factors are multiple and spinal, and trunk muscle weakness is widespread, the inclusion of the pelvis in the fusion to act as a stable base for the maintenance of the erect balance position of the corrected and fused spine is quite often necessary

CONGENITAL ANOMALIES

A variety of anomalous developments in the spine, thorax, and shoulder girdle may appear with or cause lateral deviations of the spine In these cases there is no basic pattern, the natural course is seldom the same, and the deviations produced vary greatly Those of the vertebral bodies appear as either single or multiple incompletely segmented bodies, adjacently or irregularly placed, and associated with a variety of body shapes each causing a different design of curve Areas that include

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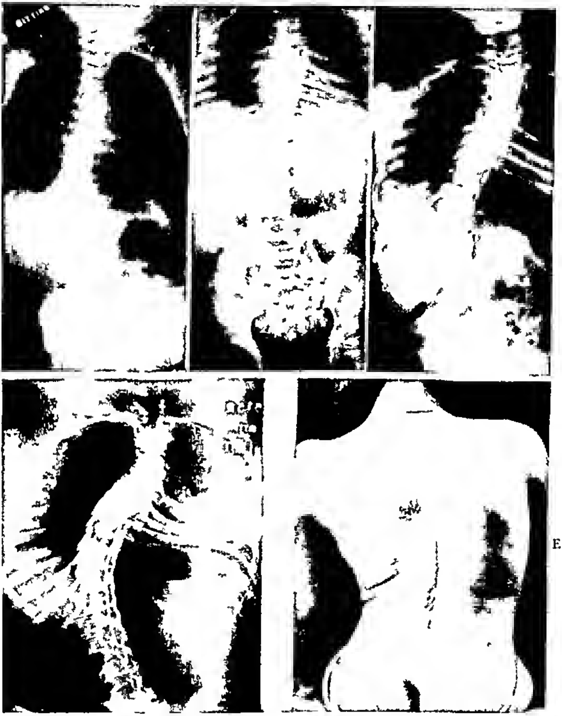

D E

FIG. 168. Paralytic curve—poliomyelitis at age two.
(A) Spine one year after poliomyelitis.
(B) Balanced spine two years after spinal fusion seventh dorsal third lumbar
(C) Spine four years after spinal fusion seventh dorsal third lumbar with recurrent deformity and displacement of trunk on pelvis through area third lumbar and sacrum.
(D) Relatively good trunk balance five years after extension of spine fusion third lumbar to sacrum.
(E) Balanced sitting posture for same patient with almost complete flaccidity of lowers and atrophied right buttock.

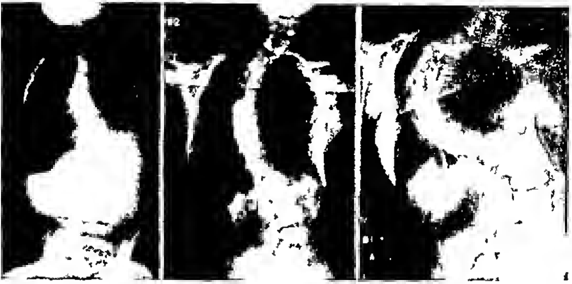

Fig 169 Hemivertebra causing scoliosis
(*Left*) Hemivertebra at seventh dorsal-eighth dorsal Left dorsal curve 28° Patient at age six
(*Center*) Progressive scoliosis due to untreated hemivertebra
(*Right*) Tragic result of refusal to permit surgical intervention Patient's actual height is two inches shorter at her present age of 16 years than at age six

Fig 170 Congenital anomaly—male aged six
(*Left*) Hemivertebra between third and fourth lumbar vertebrae
(*Center*) Hemivertebra removed and spine in process of wedging
(*Right*) End result two years after correction and spinal fusion third to fourth lumbar

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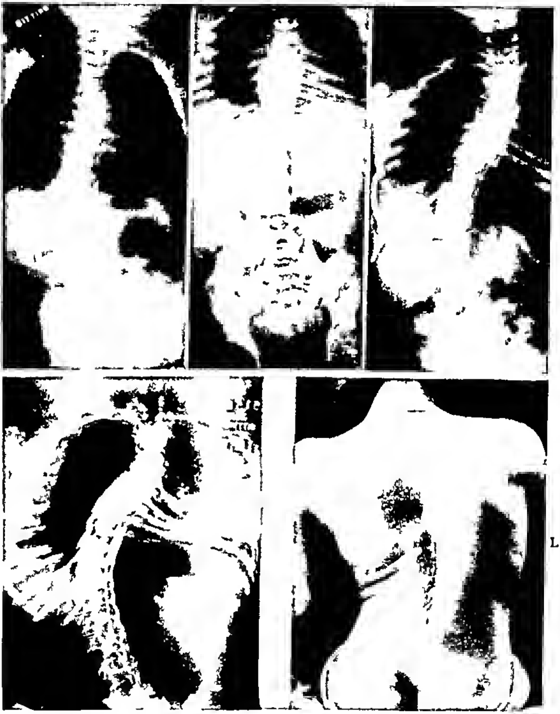
D L



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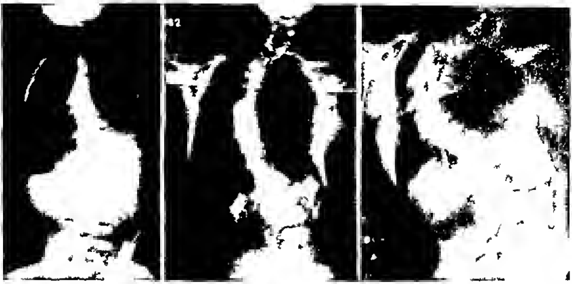

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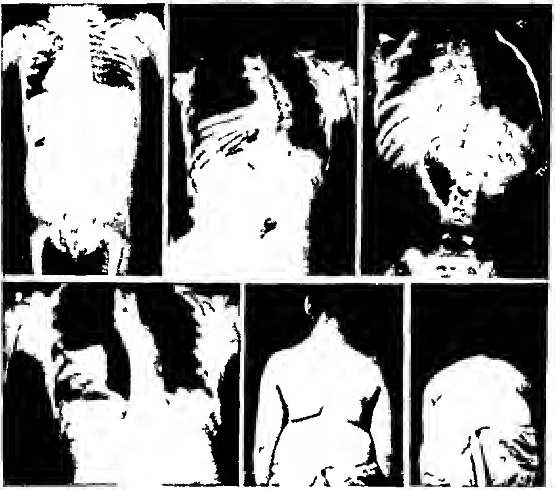
A B C



D E

Fig. 171. Scoliosis associated with unsegmented bodies and ribs—female, aged two.

(A) Multiple anomalies are present causing a 28° right dorsal curve, sixth dorsal-first lumbar, apex ninth dorsal.

(B) Over a six year period the deformity has increased to 44°. Correction of scoliosis is impossible without removal of ribs.

(C) Removal of ribs performed previous to wedging jacket correction and spine fusion.

(D) Postoperative end result. After removal of unsegmented ribs, maximum correction at 32° was achieved and spine fusion carried out fourth dorsal-second lumbar.

(E) Postoperative cosmetic result.

only two or three bodies not greatly malshaped are not likely to cause much curvature, but deformities that extend over a fairly large area and are quite fixed and associated with much trunk displacement are capable of rapid progress. In these the only flexible and correctible curve is the compensatory uninvolved portion. In this type of abnormality, the need for correction and fusion of the compensatory curve to obtain body balance must await completion of spine growth. Treatment before completion of growth will usually terminate with insufficient correction and a severely unbalanced torso, further correction being made impossible by the already fused compensa-

tory portions This is an important factor in failure or success

At times, hemivertebrae are quite symmetrically placed and balance each other *in their growth effects* These cases present no reason for surgery They may, however, be unilateral and single and cause rapid deformity (Fig 169) These are cases for correction and fusion either before or after tebra, however, the progressive deformity is usually greatly retarded When correction and fusion are performed after removal of the hemivertebra complete arrest of the deformity and at times complete correction of the deformity can be accomplished (Fig 170)

Among the deformities of the ribs are those in which fusion or failure to segment

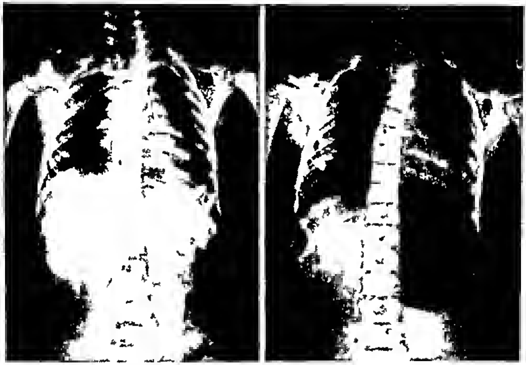
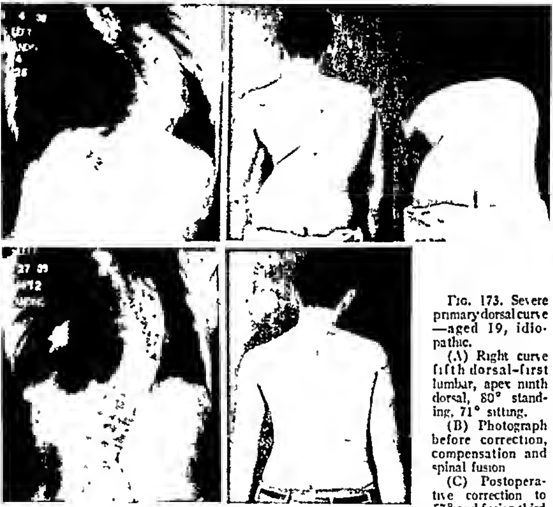


Fig 172 Sprengel s deformity surgically treated—aged five
(*Left*) Congenital anomalies are present in upper thoracic spine causing a mild left upper dorsal curve Note high position of right scapula
(*Right*) Slight increase in curve Note symmetrical position of scapulae five years later Excellent cosmetic result See also Chapter 1

excision of the anomalies The efforts of von Lackum and Smith[30] to correct scoliosis due to hemivertebrae by excision and subsequent jacket corrective treatment, while embodying a most formidable procedure have proved successful in the lumbar area In the dorsal area because of the technical difficulty of controlling hemorrhage and the lack of either satisfactory structural or cosmetic improvement, the operation appears of no value If correction and fusion are done without the removal of the hemivertebra are often associated with similar deformities in the vertebral bodies, constituting a fixed though correctible deformity of the bodies Correction may be gained in a progressive curve of this nature through plaster jacket wedging after complete excision of the deformed and unsegmented ribs (Fig 171) High dorsal deviations of the spine associated with Sprengel s deformity and torticollis require only appropriate treatment for the primary conditions (Fig 172) When in severe incor

rectible deformity, the eleventh and twelfth ribs impinge on the iliac crest and cause pain, they should be resected Rib resection for cosmetic purposes in the sharply posteriorly angulated ribs is impractical because of its formidable nature and its limited benefits.

A B



C D

Fig. 173. Severe primary dorsal curve—aged 19, idiopathic.

(A) Right curve fifth dorsal–first lumbar, apex ninth dorsal, 80° standing, 71° sitting.

(B) Photograph before correction, compensation and spinal fusion

(C) Postoperative correction to 57° and fusion third dorsal–first lumbar.

(D) Postoperative cosmetic result. The great benefits available to late cases through correction, compensation, and surgery are here clearly shown

INDICATIONS FOR SURGICAL INTERVENTION

In patients for whom surgery is being considered or where surgical indications are yet questionable, stretching of the spine and a system of symmetrical body exercises will aid greatly in increasing the flexibility of the spine should the patient later be subjected to correction. Whether determined upon at the initial visit or after observation and conservative treatment, surgery becomes indicated in three major instances: (1) Progressive curvature in a young and growing child; (2) curvature with objectionable deformity and imbalance of the trunk, regardless of whether the patient is

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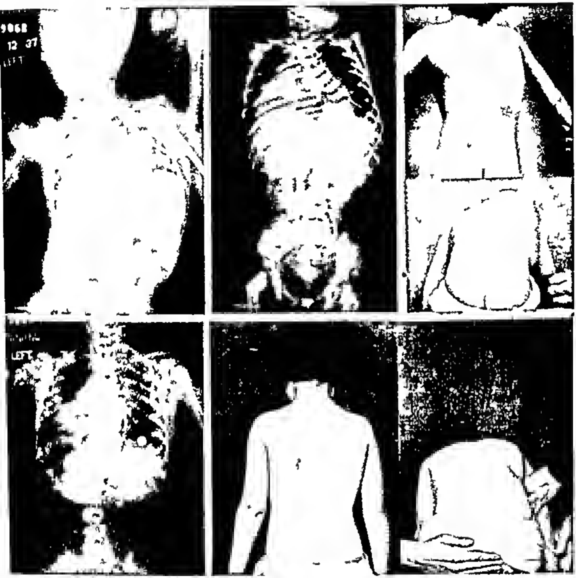


D E

FIG 174 Congenital right dorsal curve without anomalies—aged two, idiopathic

(A) Right curve, present since birth fifth dorsal–first lumbar, apex ninth dorsal, is 66° sitting

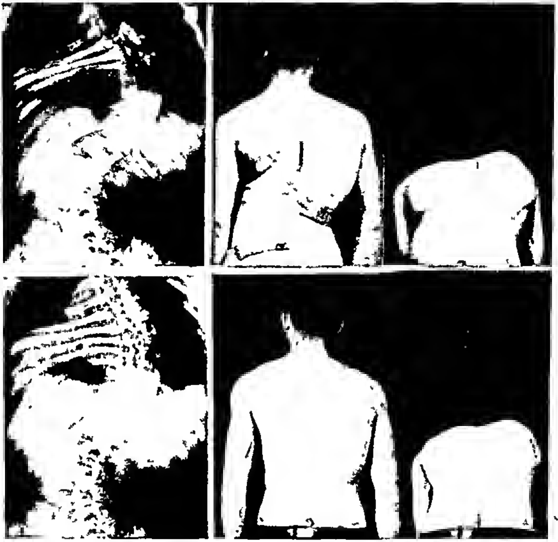
(B) Same curve as shown in (A), in lying position, is 52°

(C) Preoperative photographs showing level pelvis and shoulders but marked prominence of the right ribs posteriorly

(D) Correction obtained, remains at 35° and spine fusion is continuous fourth dorsal–first lumbar

(E) Sustained correction and excellent cosmetic result two years later are indications of desirability of early surgical intervention and applicability of method in infancy

A B



C D

FIG. 175 Moderately severe right dorsal curve—aged 22, idiopathic.

(A) Primary curve fifth dorsal–twelfth dorsal, apex ninth dorsal of 69° with a compensatory left lumbar curve of 56°.

(B) Preoperative severe decompensation.

(C) End result after maximum correction to 56° and fusion reinforced by tibial bone, fourth dorsal–first lumbar.

(D) Postoperative photographs show results obtainable in severe curves largely through compensation.

within or beyond the growth period (Fig 173), (3) pain, fatigue, and poor chest physiology Vital capacity of the chests has been studied in a series of cases, and though the findings have shown quite a wide range of difference they have not thus far been the basis for any definite change in surgical therapy

It is well to keep in mind, when surgery is under consideration that correction and fusion are applicable to a much younger group than is usually accepted Small children tolerate the procedure exceptionally well (Fig 174) Similarly, fusion is applicable in selected cases, to a much older group than is usually included since diminution of spinal flexibility is frequently not pronounced until the fourth or fifth decades and after a short period of adjustment in a corrective jacket these patients undergo the treatment without discomfort (Fig 176) In advanced cases where flexibility has largely been lost the objective is to relieve pain and disability no effort is made to correct the deformity (Fig 159) Jacket correction and spine fusion are applicable to all others in whom the deformity warrants it and in whom constitutional factors do not contraindicate it

There are few contraindications to jacket correction and spinal fusion The mortality in spinal fusion for scoliosis is less than 1 per cent since operative shock has been minimized by operating on small areas in multiple stages Carried out in one two three, or four stages the procedure seldom produces an appreciable amount of shock Though a patient may be very young or show the diminished vital capacity of a severe poliomyelitis or an old empyema or a cardiac insufficiency (the residual of subsided rheumatic heart disease) or be suffering from poor and unimproving general nutrition these cases may ordinarily be regarded as safe for surgery carried out in this manner The average case in good condition, in whom the average number of eight to nine joints is outlined for fusion, can safely be operated upon in two stages with a three week interval between stages, if blood counts reveal cytology that is satisfactory

Surgical Treatment

When, because of progressive deformity, severe established deformity or pain, surgery becomes the treatment of choice the surgeon is confronted with the two-fold objective of the return of the displaced portions of the spine and thorax as nearly as possible to their normal anatomic positions,

Fig 176 (*Top*) Flexible dorsolumbar curve—aged 35 (*Left*) Preoperative photograph in female aged 35 years The 40° curve present is from ninth dorsal fourth lumbar apex twelfth dorsal (*Right*) Postoperatively the cosmetic result is excellent despite patient's age the curve because of extreme flexibility, was reduced to 17°

Fig 177 (*Bottom*) Head helmet jacket

or to an equivalent in balance and the permanent maintenance of this correction after all support has been abandoned In mild cases with a single primary curve almost complete correction of the curve can be accomplished with relative ease As a rule in moderate and more severe deformities the maximum pressure that can be exerted is sufficient only to better align the trunk by extending the fusion to include end vertebrae in the compensatory area Complete correction in the more severe curves is not necessary for good body alignment and a satisfactory cosmetic result (Fig 175 A B C and D)

Jacket Application There are several variations in design of wedging jackets all derived from the original body jacket with one thigh and the neck chin and occiput included in the plaster devised by Risser[17] For cervicodorsal and high dorsal types a head helmet is added to provide a more secure upper lever arm (Fig 177) Both thigh and shoulder straps in place of a headpiece are incorporated in the plaster for a distal extension of the curve or for repair of a pseudarthrosis in the low dorsal or lumbar area and for fifth lumbar tilt types Occasionally the inclusion of one entire lower extremity is needed for stability

Placing a patient in a wedging jacket should be preceded by cutting the hair especially from the occipital temporal and posterior frontal regions Then on an empty stomach without medication the procedure is begun by placing a stockinet over the body including the head and one thigh (Fig 179) With the frame mounted on 30-inch horses the patient is placed on his back on the supporting canvas strap the thigh on the convex side of the curve resting on the swivel support and the head on a padded movable flat board just above the transverse bar holding the canvas strap The shoulders of the patient are two inches distal to this transverse metal bar and the arms and hands are supported on the sides of the frame The head covered by stockinet with only the nostrils exposed is suspended by loops of muslin bandage one looping around the occiput and one around the chin pinned together just over the mastoid process The ends of the loops are attached to a metal spreader suspended from a ratchet after being looped around a bracket at either side of the frame The head is tilted away from the convexity of the curve to relax the cervical and brachial plexuses and to prevent the stretch they are otherwise subjected to when subsequent wedging nears completion It should be allowed to rest on the padded board until the head piece of the jacket is to be applied A loop of muslin bandage is passed around the patient s body resting in the axilla the ends fixed to the opposite side of the frame pulling in a direction opposite to the direction of the head (Figs 178 179 180) A smooth covering of crepe paper is laid over the body and thighpiece to prevent the stockinet from adhering to the plaster and to make the undersurface of the plaster uniformly smooth (Fig 180) Felt pads are then applied over the inner thigh and sacrum beneath the anterior and posterior hinges over the anterior superior iliac spines axilla posterior rib prominence chin and occiput A thick felt pad split and enlarged with a cotton center is placed over the convex side of the thorax flank or iliac crest as a fulcrum point for the wedging (Fig 181)

Plaster application is begun by first applying the spica well up around the thorax to the axillae with multiple reinforcements of plaster splints across the hip region anteriorly and posteriorly Thereafter the head board is removed and the ratchet taken up until the head is suspended in a tilted position in slight hyperextension The head piece is then applied by making a substratum of plaster around the head and neck except for the face and dome of the skull extending downward to and overlapping the upper end of the portion of spica already applied In this procedure

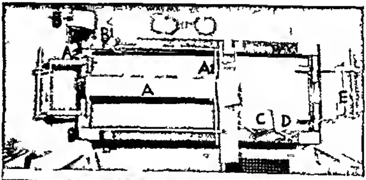


FIG 178 Frame for application of the several types of jackets
(A) Canvas strip suspended from removable bar (A 1) and made taut by ratchet at (A 2)
(B) Swivel support for thigh
(B 1) Metal fixture in frame for changing position of swivel leg support necessary for all sizes of subjects
(C) Angle position of metal head *traction apparatus made possible* by metal loop (D) from where traction by ratchet (E) is made

FIG 179 Frame resting flat on 30 inch high wooden horses Patient on frame in correct position for applying jacket Note tilted position of head countertraction through axilla and leg on swivel support

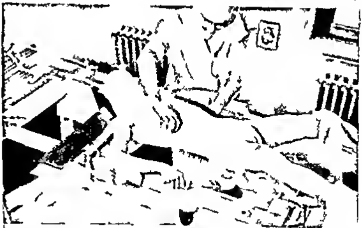


FIG 180 Crepe paper applied over stockinet

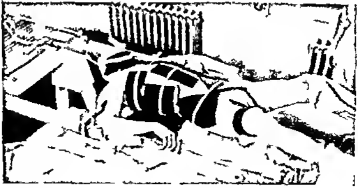


FIG 181 Felt pads applied

four inch circular plaster is applied over multiple layers of plaster splints both anteriorly and posteriorly until a thick support of plaster is made completing the shoulder and helmet portion

The hinges may then be applied, buried in plaster reverses and circular bandages If greater force than usual is anticipated in

The thickness and the reinforcements of the jacket are naturally determined by the stresses to which the jacket will be subjected in each given case, and must be strong enough to support each part well from the time of application A break in the jacket or a softening at any point, such as will occur where the amount of plaster is

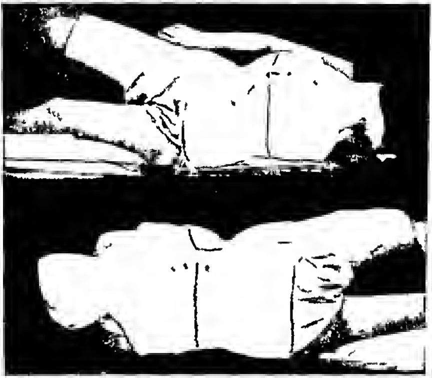


Fig 182 Completed jacket Position of hinges and site at which cutting out is done for wedging are penciled on outside of jacket

correction it is well to defer application of the hinges for a week or ten days At that time grooves can be cut in the plaster and the hinges cemented in with loose plaster and covered by circular bandages After the incorporation of the hinges the jacket is trimmed about the head and neckpiece the axillae and the perineum (Fig 182) During the first few days after jacket application weight stresses should be avoided on the hyperextended headpiece and thigh portion by the provision of sandbag support for each

insufficient, is often impossible to repair and necessitates reapplication Securing of hinges that have become loose during the wedging process is almost impossible, and hinges not well fixed in the plaster may loosen just as correction is nearing completion This so weakens the jacket that loss of correction occurs jeopardizing the result Several weeks may be lost by the consequent necessity of re applying a new jacket and repeating anew the entire process of correction

In the high cervicodorsal curve, where

the hinges are placed high, the jacket can best be hinged through lateral cuts in the plaster to the axilla In the high dorsal curve correction can best be obtained by lateral cuts low down into the lateral aspects of the jacket in the usual way (Fig 182) In both instances, when unusual force must be exerted to obtain correction, delayed application of the hinges is regarded as the most certain manner of assuring their stability Immediately after the application of the jacket, massage of the chin and the lower extremities should be started, to relieve annoying pressure and muscle aches

The Wedging Procedure After two weeks, the jacket is usually sufficiently dry to assure its stability and the stability of the hinges in the plaster The jacket is then cut completely across at the apex of the hinges, dividing the jacket into two parts—a hip spica and a shoulder head spica—held together by the hinges The side of the convexity of the curve is widened from the hinges laterally to permit bending in that direction With the jacket cut out for wedging, lugs[8] and a small turnbuckle are applied, and the actual process of correcting the curve is under way Each day several turns of the turnbuckle are made (Fig 183) When, as determined by palpation and appearance, correction appears adequate, an x ray picture is taken to determine the amount of correction Should the correction be adequate, the jacket is ready to be 'boxed in' (Fig 185) If not, the wedging process is continued until further x ray check-up indicates a satisfactory correction and alignment (Fig 184)

The technic of ' boxing in" then follows A long, basswood, plaster covered strut is made and fixed so as to join the headpiece and thighpiece of the jacket This is allowed to dry for ten minutes, after which the lugs and turnbuckle are removed The body at the depths of the openings in the jacket is padded with felt and the openings closed with circular bandage, this filled in portion is spoken of as a vest Struts extending from the headpiece to the body piece at the shoulder and across the concave side of the body of the jacket are then applied (Fig 185) After the struts and vest have dried for 48 hours a posterior fenestration is made in the jacket approximately over the area of the curve (Fig 186) A transverse gentian-violet line is made across the skin of the back, passing over any one spinous process within the area of the curve to be fused (Fig 186) A thin wire is strapped over this stain and an x ray made In noting the spinous process over which the shadow of the wire is shown, orientation is made possible by reason of the stain on the skin when surgery is later performed From the marker x ray film, the amount of correction is measured and recorded, and the area for fusion determined

The flexible spine with only moderate deformity will correct quickly, whereas the more severe curves that have lost a portion of their flexibility must be "turned up" much more slowly A flexible curve of moderate degree in a child may be correctible in a few days a marked curve with limited flexibility in an older person may require several weeks for completion of maximum wedging It must be remembered that in severe curves of fairly long standing the soft tissues throughout the concave side have become quite shortened They must stretch slowly as correction takes place and the limits of correction are somewhat dependent on the amount of stretch these tissues will stand

In mild curves, full correction of the curve, or of the ends of the curve, is reached early Several films may be necessary during the process of correction, since perfect balance must be arrived at and, in over correction by wedging, the process must be reversed until proper alignment of the end vertebrae is reached Where a curve is moderate or severe and flexibility is moderately or greatly limited, balance is attained by maximum correction of the curve and the alignment, in addition, of one or two verte

Fig 183

Fig 184

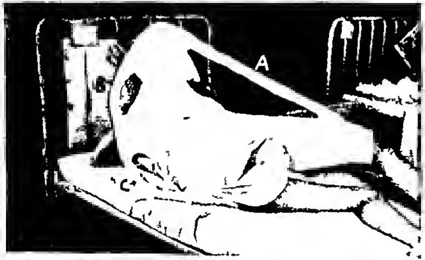


Fig 185

Fig 186

For legends see p 183

bral bodies beyond the upper and lower limits of the actual curve (Fig 187) The procedure in the severe cases where maximum correction is desirable and where maximum force is therefore applied necessarily requires added time to prevent pain and pressure sores and wedging should proceed until continual turnbuckle turning as visualized by x rays and as determined by the patient s tolerance accomplishes no further correction It should be kept in mind that a satisfactory area for fusion can be selected almost any time in the corrective process after a moderate amount of correction through turnbuckle force has been exerted The chief advantage of greater correction or greater compensation thereafter is a shorter fusion area

In the younger children where loss of flexibility is slight properly placed felt pads as applied beneath the jacket usually buffer all pressure points sufficiently to avoid pressure necrosis but in the less flexible curve in the older age group pressure sores occasionally develop over an unpadded area over the scapulae or other prominences of the bony thoracic cage Because of too rapid correction at times beneath thick felt pads a point of pressure necrosis may appear over the chin the occiput sacrum iliac spines or a poorly trimmed margin of the cut edge of the jacket The jacket must be constantly inspected and trimmed to avoid this complication particularly after the wedging has progressed to where the pressure is great

As wedging pressure increases and becomes quite advanced occasionally numbness in the arm deltoid weakness or beginning wristdrop appear to warn of the too great or too rapid stretching of the brachial plexus This same nerve phenomenon may appear early in the wedging process from direct pressure on the cervical nerve roots if the headpiece is applied too snugly around the neck Brachial palsy in any degree is a signal to stop the process of correction in order to somewhat relax the tension until recovery of power is seen Thereafter correction should be resumed cautiously and again halted upon recurrent signs of palsy

Selection of the Area for Fusion During the process of wedging all estimations of correction and alignment are made directly from x ray films taken through the jacket during the progress of correction After wedging is complete the jacket boxed in cut out for operation and a marker x ray (Figs 203 B 204) made the area to be fused is selected from the latter film Correction of curves may be complete or partial In the less severe curves where it is almost complete the ideal fusion area is selected as outlined by Ferguson from the final correction or marker film The area for fusion is chosen as follows

1 The minimum area must include every vertebra in the primary curve

2 The ideal fusion is one which includes the minimum fusion area and in which the end vertebrae are parallel to each other and at right angles to the line joining their centers In the final result the end vertebrae of such a fusion will be parallel and transverse to the axis of the trunk

Where fusion into compensation is necessary no all inclusive rule for selecting the area can be outlined Each case requires individual consideration

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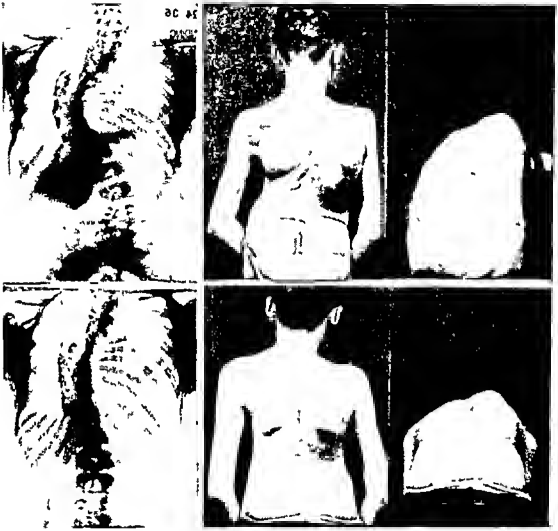
FIG 183 Wedging process begun Lugs and turnbuckles applied Correction by turnbuckle begun

FIG 184 Wedging completed when x ray indicates satisfactory correction or alignment

FIG 185 Jacket boxed in Correction and alignment completed as shown by x rays taken through plaster with strut (A) joining head and legpiece lugs and turnbuckle removed and struts (B) and (C) applied

FIG 186 Jacket fenestrated for operation Marker applied on skin 48 hours after application of struts and vest a posterior fenestration is made exposing as near as possible the area selected for fusion Poster or hinge is removed in making the fenestration A marker x ray is then made (see Figs 203 B and 204 B)

A B



C D

FIG 187. Primary dorsal curve—aged 10, idiopathic

(A) Right curve, fifth dorsal-twelfth dorsal, apex ninth dorsal is 77°, with onset at 1½ years.

(B) There is progressive severe deformity and decompensation unusual at so young an age.

(C) Postoperative correction at 30°. Fusion fourth dorsal-first lumbar Because of marked loss of flexibility, satisfactory alignment required inclusion of two vertebrae above and one below actual limits of curve

(D) Postoperative cosmetic result three years later shows good compensation and excellent posture and balance.

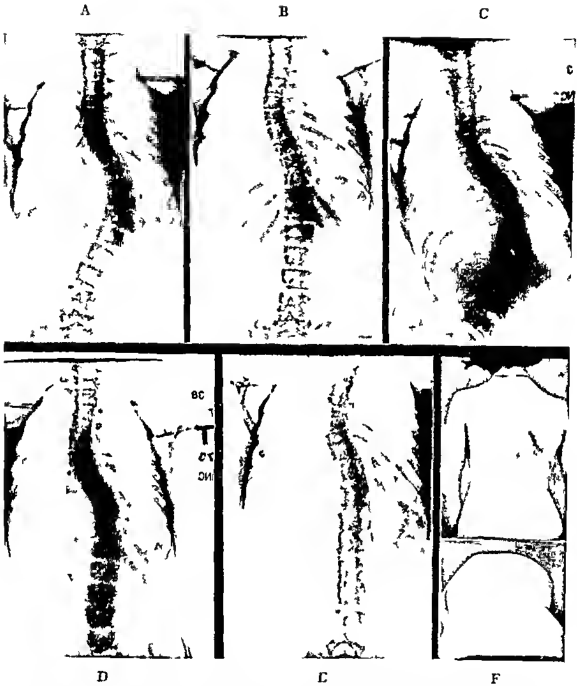


Fig 188 Asymmetrical double primary curve—aged 11 idiopathic

(A) *There is a short high right dorsal curve third dorsal seventh dorsal apex fifth dorsal* 22° standing long left dorsolumbar curve seventh dorsal–second lumbar apex eleventh dorsal 40° standing

(B) *Same curves—21° 40° respectively in lying position*

(C) Right pelvic tilt showing dorsolumbar curve increased to 47°

(D) Left pelvic tilt showing dorsolumbar curve reduced to 26°

(E) Correction and fusion seventh dorsal third lumbar Curve is *stationary at 16° three* years postoperatively Dorsal curve has not spontaneously reduced

(F) Postoperative photograph indicates excellent result and describes a satisfactory manner *of treating this uncommon type of double primary curve The upper, essentially nondeforming* curve should be treated conservatively after correction of the longer and more deforming dorsolumbar curve

In the moderate primary curves with secondary returns to the erect (mild compensatory curves) spontaneous compensatory-curve correction and balance for maximum correction obtainable, occur with minimum fusion area or with extension of fusion into compensation if necessary. In similar primary curves but where the compensatory curves are almost as great as the primary one a departure must be observed from the rule of correcting the primary curve to a point where the bodies of the end vertebrae are parallel to each other. A variable residual inclination of the end vertebrae consistent with trunk balance must be permitted. Fusion is then extended beyond the ends of the primary curve into the adjacent compensatory segments. In this instance the determination of the actual fusion area and decision as to whether or not one vertebra or more beyond the ends of the primary curve should be included (Fig. 189) is made after maximum correction has been obtained by the wedging jacket. The decision hinges on both the amount of correction obtained in the primary curve and the amount of spontaneous reduction in the compensatory curve.

In the more severe primary dorsal curves (Figs. 173, 175 and 189) where because of less effective corrective effort, or because of the undesirability of obtaining more than partial correction of the primary curve, the end vertebra of the primary curve remains partially inclined in the direction of incomplete correction, proper balance and alignment of the trunk also necessitate extension of the fusion area beyond the limits of the primary curve. One must be guided in the determination of the fusion area in moderate and severe curves, where loss of body balance is marked and where primary curve fusion areas are not sufficient, by a study of the comparative spontaneous lumbar flexibility as seen in tilt views and the primary dorsal curve correctibility as seen in the bend views. Here the degree of forced correction obtained in the primary curve and the spontaneous correctibility shown to exist in the compensatory curve or curves (as shown in the bend and tilt views) determine the extent into compensation that fusion should extend. Superimposition of the final correction film over the pelvic tilt film made in the opposite direction is a convenient method of making the estimation of body balance and if the vertebrae immediately adjacent to the primary curve in the compensatory area are superimposed individually, one at a time, a minimum level in the lower adjacent compensatory segments where body balance is seen to exist indicates the maximum lower level for the fusion. The maximum upper level can be estimated by determining the upper vertebral body that has a comparatively similar opposite inclination in balance to the lower body consistent with balance in the upper compensatory curve. In these instances too great correction of the primary curve would, because of limited flexibility in the lumbar and dorsal or cervical compensatory curve, terminate in an inadequate amount of compensatory curve reduction and a residual asymmetry of the hips or shoulders or both. In similar severe dorsolumbar and lumbar curves alignment of the fourth lumbar is made with the proximal upper segment of the primary curve consistent with the spontaneous correction apparent in each compensatory area, using again the superimposed films for making the determination. Subsequent spontaneous alignment of the pelvis thereafter brings about balance of the pelvis. Should residual disalignment of the pelvis persist, jacket correction and alignment is indicated. The rule is also modified in the presence of double primary curves where both curves are selected for correction and fusion, in which instance the curve of least flexibility is subjected to maximum correction and fusion and the curve of greater flexibility thereafter corrected and aligned. The rule is additionally varied in instances of a double primary curve, where, because of

A B

C D

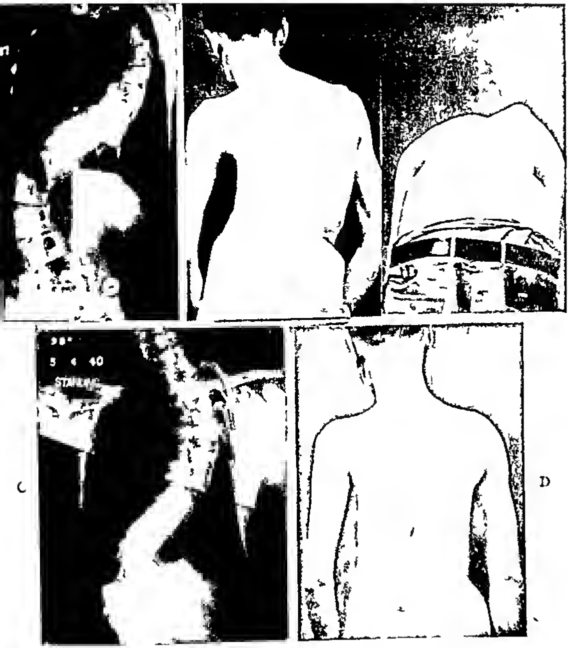


FIG 189 Severe dorsal curve—aged 15, idiopathic

(A) Right primary curve of 82°, first dorsal–eleventh dorsal, with apex at seventh dorsal compensatory left curve eleventh dorsal–fourth lumbar, 59° standing, 52° lying

(B) Cosmetic deformity is well shown Decompensation has occurred and there is a shift of trunk to right

(C) Postoperative end result following spine fusion seventh cervical twelfth dorsal Because of limited flexibility in compensatory lumbar curve to 53° sitting with left pelvis elevated, correction was intentionally limited and final correction remains at 50°

(D) Adequate decompensation in secondary curve has aided greatly in obtaining body balance

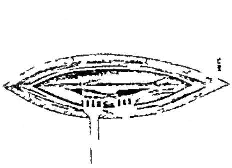


Fig 190

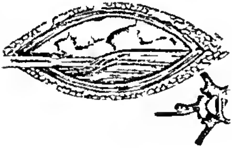


Fig 191

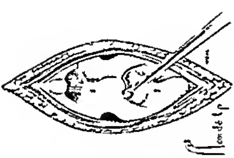


Fig 192

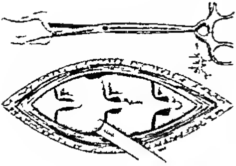


Fig 193

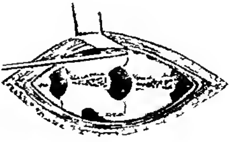


Fig 194

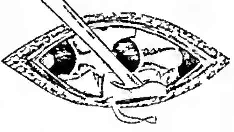


Fig 195

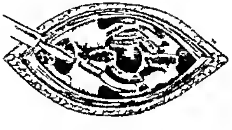


Fig 196

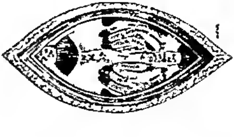


Fig 197

For legends see p 189

one portion of the curve being greater or more deforming and the other being relatively less or nondeforming it is believed that the correction of the greatest deforming component may adequately balance the body by correction and fusion of this one component In this case, after correction and fusion, corrective exercises for body balance may be carried out to determine the result with the surgical treatment of only one of two primary curves (Fig 188) In the presence of natural fusion at the apex area as is quite frequent in curves of long standing, or where the greater part of a long standing severe primary curve is spontaneously fused *the possibilities of correction may be very* slight or absent If the compensatory areas above and below have been kept flexible, body alignment with very limited or with no correction of the curve as well as adding stature often greatly improves alignment through compensation

TECHNIC OF FUSION

Induction usually with gas oxygen, and ether is carried out with the patient lying in the jacket on the back, after which he is turned over, face down, with head fixed in the headpiece of the jacket by a strap of adhesive across the forehead and attached to the plaster headpiece Proceeding through the fenestration in the jacket and guided by the marker stain on the skin, a midline incision roughly extending one vertebra above and one vertebra below the area intended for fusion is made Towels are applied and fixed with Michel clips and the spinous processes are exposed by subperiosteal dissection, facilitated by gripping each spinous process firmly with a forceps The interspinous ligaments are split to connect the split periosteum over the spinous processes

With a periosteal elevator the subperiosteal dissection is carried laterally from each lamina to and slightly beyond the articular facet *The superficial portion of* the ligamentum flavum is excised with a curette and with a curved or straight osteotome, depending upon the type of articulation encountered the articular facet is excised the complete removal of the cartilage from the depths of the facet is completed with a curette The tips of the spinous processes are split with a straight osteotome, removed, and each one of the split halves is wedged into the excised articular facet, obliterating the space Chips are cut from the spinous processes and laminae and interwoven across the interlaminal space The same procedure is carried out throughout the selected fusion area for each joint individually *The extra bone* occasionally needed can be obtained from the ilium, the tibia or from a bone donor, and any bone obtained in excess of that needed at a given procedure may be buried in the wound until needed at the *following* stage of fusion Layer closure is done using

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Fig 190 *Technic of fusion* Midline incision showing splitting of intermuscular raphé and interspinous ligament, most important in assuring a bloodless field

Fig 191 *Technic of fusion* Hibbs' chisel elevator for bloodless subperiosteal dissection of spinous process and laminae

Fig 192 *Technic of fusion* Hibbs Spratt curette excising ligamentum flavum

Fig 193 Technic of fusion Curved osteotome for excising articular cartilage in antero posterior arch articulations of dorsal and lumbo sacral area with stick sponge, indispensable in clear visualization of steps especially in bone work

Fig 194 *Technic of fusion* Straight osteotome for excision of cartilage from internal external posterior arch articulations in lumbar area

Fig 195 *Technic of fusion* Gauze tail packs, so important for hemostasis throughout each surgical step

Fig 196 *Technic of fusion* Bone chips interlacing across and bridging interlaminal spaces

Fig 197 Technic of fusion Completed fusion bed with interlaminal spaces well bridged with several layers of chips and articular cartilage of facets removed and replaced with bone chips

silk for the skin, and a dry dressing is applied

A stockinet cotton pad removed from a warmer is placed over the dressed surgical wound and the fenestration in the jacket snugly closed with plaster Sutures are removed after two weeks by again cutting a fenestration in the jacket and a new marker is applied and x rays are taken to verify the area already fused This process is repeated after each surgical stage of the fusion finally closing with plaster for the duration of the three month period which follows the final surgical procedure Because of the lengthy portion of the spine selected for fusion in most instances and to prevent postoperative shock fusion is usually performed in two or three stages with an allowance of a three week interval between each procedure unless contraindicated by low blood count or other factors Each stage is preceded by a 24 hour sterile preparation

Occasionally there may be complications in the surgical procedure Accidental puncture of the membranes of the spinal cord is at times followed by leaking of fluid into the dressing for several days postoperatively At the time it occurs the opening should be packed as in making hemostasis and the remaining surgical steps completed as usual

Postoperative wound infection may develop beneath the muscle layers or in the subcutaneous tissue with the usual signs of infection though much later In superficial infections adequate provision for free draining of the purulent contents should immediately be provided and in deep infections splitting of the spinal muscles should be done and free drainage and extrusion of loose chips permitted Hot packs thereafter greatly aid in relieving pain and promoting healing If so cared for fusions may succeed in spite of infections due to surgery

CONVALESCENT TREATMENT

Jacket treatment postoperatively is divided into three 12 week period At the conclusion of the final surgical stage of fusion the patient is kept recumbent for 12 weeks During this time an adequate nutritional regime is instituted At the close of this period the wedging jacket is removed by soaking in a tub and an immediate roentgenogram is taken The curve is measured and the fusion closely inspected at each segment A semi bent jacket is then applied for a second 12 week period The method of application is relatively simple (Figs 198 199 200) The patient is placed face down on a frame and the pelvic portion of the jacket is applied followed by the thoracic section Distraction is made in the direction of correction and the midportion of the jacket connecting the overcorrected upper and lower portions is applied The cast is allowed to dry for from 15 to 20 minutes and then with the patient seated on a stool it is trimmed over the axillary portions and anteriorly over the thighs A shoulder strap is carried over one or both shoulders to insure support above (Fig 201) The patient is kept recumbent for 48 hours until the jacket is thoroughly dry and is ambulatory thereafter

When the second 12 week period has elapsed the jacket is removed and an x ray taken to observe the progress of fusion and to measure the curve The straight jacket is applied immediately thereafter for another 12 weeks The method is similar to the application of the semi bent jacket, except that distraction or overcorrection of the spine in any form is omitted (Fig 202) It is during the second 12 week period of progressive ambulatory activity in a semi bent jacket that deficient areas either solidify and become confluent or continue deficient and permit continued loss of correction This period consequently is the one in which in most instances the fate of the fusion mass is finally determined

At the close of the final immobilization period all support is removed and the degree of residual curvature and the solidity of the fusion are ascertained by roentgen study This is checked at one to three month

Fig 198

Fig 201

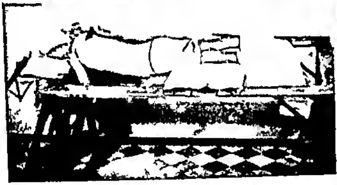

Fig 200

Fig 202

Fig 198 Application of semi bent jacket Frame arranged for application of semi bent and straight jackets Patient lies face down on canvas strap with head and legs at opposite ends of same table used in applying wedging jacket Thighs lie over pillow (A) face and head over pillow (B) and hands grip bar (C)

Fig 199 Application of semi bent jacket Stockinet and pads applied followed by a circular cuff of plaster snugly applied around hips and upper thorax After plaster cuff hardens intervening gap is bridged with rolls of plaster while traction is applied in direction curve has been corrected

Fig 200 Semi bent jacket partially completed Distal cuffs connected making body portion of jacket complete

Fig 201 Completed semi bent jacket Plaster shoulder strap completes jacket Patient is set upright on a stool thigh and axillary margins trimmed upper edges of jacket greensticked against anterior and posterior chest walls and shoulder then padded with felt and a plaster cuff applied to one (concave side of curve) or both shoulders

Fig 202 The straight jacket Body is permitted to assume as near as possible a normal balanced position Position on frame same as in application of semi bent jacket No preliminary traction cuffs are placed

FIG. 203 For legend see p. 193.

intervals and by examination of the fusion area ruling out areas of tenderness, until the certainty of solid mature fusion is demonstrated by physical and roentgen evidence and a fixed and unchanging angle in the curve After removal of all jacket support, at the termination of the active surgical regime, massage over the area of operation as well as symmetrical corrective exercises should be carried out to rehabilitate the long inactive muscles and to aid in the more rapid reduction of the compensatory curve

FUSION, DELAYED UNION, AND PSEUDARTHROSIS

Even though the surgical technic of spinal fusion over several joints is carried out with uniformly good technic and solid fusion occurs throughout most of the area, fibrous union does occasionally occur at one joint, or less frequently at two or more joints A fusion deficiency may exist as a slightly or moderately delayed union or as a permanent failure of union, the latter is the true pseudarthrosis In design these defects may be a complete broad transverse interlaminal gap or as an almost hairline fine variably irregular transverse or oblique defect, traversing the fusion plate from side to side

Clinically, they appear as areas through which loss of correction takes place at which site local tenderness almost always can be elicited and where fatigue, ache, or pain is common (Fig 203) Roentgenographically, where the defect is wide, it will appear as an obvious break in the otherwise normal bony continuity In the hairline type the roentgen evidence is more likely to appear as an area of increased condensation the defect being very narrow and obliterated by the overlapping bone shadows

At operative exploration, the broad interlaminal defect is seen to be filled with variably dense fibrous tissue, adherent to the periosteum and evidenced by the difficulty encountered in stripping the otherwise easily stripped periosteum overlying the fusion plate The fine, hairline pseudarthrosis is evident by a similar, though smaller, transverse area of adherent fibrous tissue interrupting the smooth bony fusion plate Motion is variably demonstrable depending on the density of the pseudarthrosis at times being great, while at other times being difficult to demonstrate

Delayed bone repair either terminates finally in complete union occasionally after many months, or as a pseudarthrosis Delayed union or pseudarthrosis persisting any great length of time beyond the period of immobilization in the wedging jacket permits loss of correction and the gradual recurrence of the original deformity, plus further progress in the curve in the growing child Union occurring after loss of cor

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FIG 203 Untreated pseudarthrosis in dorsal curve

(A) Precorrection film, right curve fifth dorsal–second lumbar, apex ninth dorsal, 62° standing

(B) Jacket correction completed Curve reduced to 31° (maximum correction obtainable) Preoperative marker film

(C) Loss of correction to 52° All support has been removed (36 weeks postoperative) and although there is no roentgen evidence of fusion deficiency there is loss of correction ninth dorsal–tenth dorsal only, with pseudarthrosis not clearly visible on film Exploration refused

(D) Deformity has completely recurred Since growth period had not been reached when fusion was done the deformity, through the only deficiency ninth dorsal–tenth dorsal recurred completely and progressed past the point when treatment was instituted Curve is 73° Intervening films reveal slow gradual loss of correction

(E) Precorrection photograph, Trunk is shifted to right and cosmetic deformity is moderately great

(F) End result—after six years Recurrent deformity and unaltered progress in this curve exemplify that fusion failure at one joint compromises completely the entire corrective treatment

rection carries greater clinical significance than the pseudarthrosis since before re correction can be done an osteotomy of the fusion plate must precede the re-correction whereas in the pseudarthrosis correction can be regained through the defect, preliminary to its repair Occasionally an exploration reveals solid fusion, even though evidence of fusion failure has been constant in steady slow loss of correction almost to the time of exploration Loss of correction approaching dangerously a recurrent loss of symmetry and balance, however justifies exploration (Fig 204)

A B C D E

Fig 204 Delayed union

(A) Left dorsolumbar curve at 40° apex at first lumbar

(B) Correction in wedging jacket Marker x ray with maximum correction to 12° Spinal fusion tenth dorsal–third lumbar

(C) Immediate end result with correction remaining at 12°—after 36 weeks in jackets

(D) Loss of correction to 20° at twelfth dorsal first lumbar

(E) Postoperative end result After exploration and finding of solid fusion correction remains at 20°

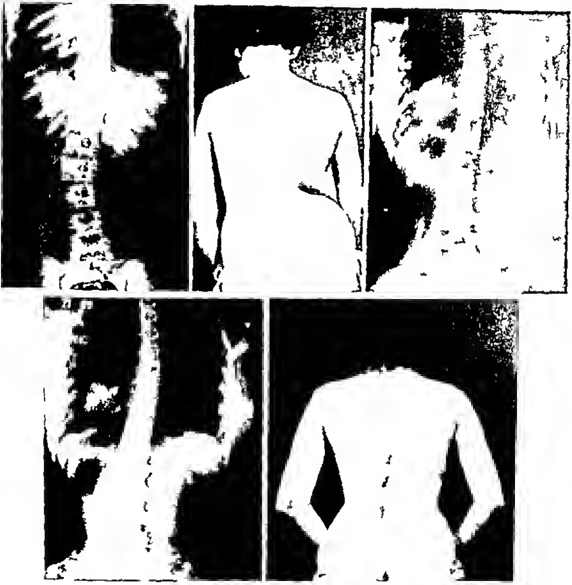
TECHNIC OF REPAIR IN PSEUDARTHROSIS

When an exploration is carried out, whether attended by recorrection or not, fixation of the spine in a plaster jacket, fenestrated posteriorly, should precede the exploration At operation the entire fusion area is exposed, even though the localized site or sites of possible fusion deficiency have been quite amply demonstrated by x ray and point tenderness preoperatively Thereafter, exercising the usual great care of the underlying membranes just as in a primary procedure, the fibrous tissue bridging the defect is curetted away completely, and the edges of the adjacent margins of bone undercut, making a trough in which bridging chips of bone will be secure Chips are then laid across the defect, in large numbers, in each instance removed from the thick normal fusion plate Pseudarthrosis repair usually succeeds Postoperative recumbency and plaster immobilization are continued, in most instances for from eight to 12 weeks, after which union is usually adequate In severe deformities where much correction has been obtained longer periods of immobilization are necessary Routine observation for several months however, is necessary to be assured of solid fusion (Fig 205)

EXTENSION OF DEFORMITY—SHORT FUSION AREAS

Complications other than fusion defects occasionally occur The time of onset and the area over which the imbalance factors

A B C



D E

FIG 205 *Corrected pseudarthrosis in dorsolumbar curve*

(A) Preoperative film showing left curve tenth dorsal fourth lumbar apex first lumbar (40° standing 25° lying) at age 13

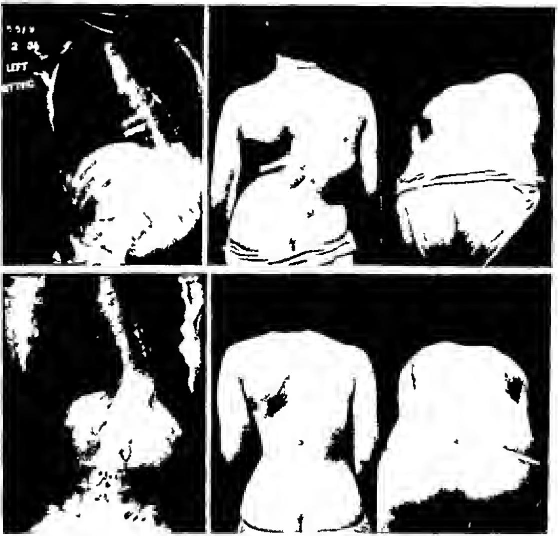
(B) Photograph of spine made before correction was begun note pelvic asymmetry

(C) Postoperative film showing spine fusion tenth dorsal fourth lumbar after jacket correction to 5° This was followed by loss of correction to 17° by pseudarthrosis second lumbar–third lumbar Recorrection was obtained in wedging jacket to 10° Exploration and repair of pseudarthrosis terminated with corrected curve stationary at 11°

(D) Postoperative film three years later correction has been fully maintained

(E) End result three years later

A B



C D

FIG 206 Incomplete fusion area

(A) Spine fusion eleventh dorsal seventh dorsal previously performed elsewhere in a right curve sixth dorsal–second lumbar, apex tenth dorsal Curve has recurred through unfused portion of primary curve

(B) Photographs show recurrent cosmetic deformity present when fusion area does not encompass full extent of primary curve

(C) End result Spine has been recorrected and fusion area extended from eleventh dorsal third lumbar Fusion is complete from seventh dorsal third lumbar

(D) Cosmetic end result Body balance has been restored

exert their deforming influence are extremely variable Just as within a primary area of involvement these deforming forces are progressive in their course throughout the spine growth period and manifest by increasing deformity, so the area over which these forces operate may extend to include one or several additional segments They constitute an additional deforming factor, and in their early development this extending area will be apparent only if a series of films are carefully studied With progress, the deformity will appear clinically In the unoperated, this progression will be noted only in increasing deformity in those already operated upon, it will be manifest in partial recurrence of the deformity taking place beyond the area of the original fusion This recurrence of deformity should be regarded in the same light as a short fusion and where necessary the deforming end segments should be subsequently aligned preliminary to a supplementary fusion (Fig 206)

PARAPLEGIA

With all the varying degrees of deformity and the rapidity with which some develop the infrequent development of cord pressure signs would seem unusual However, only rarely do pressure signs spontaneously develop over the apex of a rapidly growing and severely deforming spine Laminectomy at the site of too great tension has been shown to promptly relieve these signs when they do occasionally appear As an operative complication trauma to the spinal cord (the esult of a curette or other surgical instrument contacting the cord directly, or through sudden pressure against the membranes) may produce temporary or permanent partial postoperative hyperreflexia or localized flaccidity

COMMENT

Despite the still greatly deficient knowledge of the etiology of scoliosis a clear perception of the natural clinical course coupled with an adequate method of correction and stabilization of the deformed spine, has gone far toward altering the prospect of the structural scoliotic patient By recognition of the early findings careful observation, and intervention at the proper time, severe deformities can be avoided and the milder deviations completely corrected Faith should not be placed in conservative means, and all severe deformities occurring with such methods definitely should be regarded as cases of neglect It cannot be emphasized too strongly that scoliosis is in most instances, a progressive deformity throughout the growth period o the spine and that correction and fusion presents the most effective plan of treatment yet devised When more universal recognition is given to the fact that delay in the institution of surgical treatment is the main factor that jeopardizes the cosmetic results and permits deformity symptoms and disability in later life, a more stable concept of this progressive attainment of modern surgery will have been reached

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SECTION TWO

PARALYTIC DISORDERS

SECTION TWO

PARALYTIC DISORDERS

7

Anterior Poliomyelitis

MATHER CLEVELAND, M D

Anterior poliomyelitis is an acute infectious disease which is probably infinitely more widespread than formerly has been believed It occurs sporadically, and at times reaches epidemic proportions Its mode of transmission and the intermediate host, if any, are unknown The terrifying manner in which the disease strikes leads to almost hysterical fear during epidemics For the most part the disease has a seasonal incidence from June to September, inclusive During the epidemic of 1916 in New York City there was an incidence of 13,224 recorded cases with a mortality of 25 per cent, while in that of 1931 there were 6,189 cases with but 10 per cent mortality During this latter epidemic it was noted that of those patients seen and recognized in the pre paralytic stage, only 17 per cent developed paralysis as a sequel of their disease It may, therefore, be concluded that in earlier epidemics only those unfortunates who developed paralysis were recognized and classified as instances of anterior poliomyelitis

It is now known and understood that in this general infectious disease paralysis is merely an unfortunate complication which many victims escape In those patients who do develop this symptom of paralysis there is always hope for improvement or even total recovery of muscle function This recovery of motor power varies with the extent of damage to the motor nerve cells of the spinal cord In those few patients in whom varying numbers of these motor nerve cells have been destroyed and replaced with scar tissue there can be no improvement in those muscles whose nerve cells have been so destroyed

Though there is every hope, but as yet no certainty, that this disease will in time be as well understood and controlled as are diphtheria or smallpox, there are to date no specific preventive measures and no certain therapeutic agents which have been proved to have influenced the onset or course of this infection It is not within the scope of this writing to attempt to enumerate the vast array of experimental work at present under way along the lines of prevention and specific treatment of anterior poliomyelitis The present status of the epidemiology, prophylaxis, and treatment of anterior poliomyelitis, the acute infection, has been extensively reported in the International Bulletin recently published by the National Foundation for Infantile Paralysis If, as there is every reason to hope, success attends these efforts to specifically prevent or cure the disease, the treatment of the paralytic manifestations will no longer be one of the major problems of bone and joint surgery Then treatises on the subject of the cripple due to anterior poliomyelitis will in time become as quaint as Defoe's "Journal of the Plague Year"—1665—when 70,000 persons perished in London of a disease that medical knowledge is now able to check and quickly eradicate However, this Utopia is not yet reached and we must continue with the

means at hand to alleviate rather than to prevent or cure anterior poliomyelitis

STAGES OF THE DISEASE

This disease is usually described as passing through three fairly well defined stages and since the treatment is markedly different in each it is necessary briefly to describe these stages

The Acute Stage

This lasts from the onset of the disease until the disappearance of muscle soreness The treatment during this period is absolute rest and the prevention of deformity and, in addition, the absolute avoidance of any measures which might defeat these two cardinal requisites This stage of muscle soreness, which usually lasts from six weeks to two or three months, may be greatly prolonged by ill advised massage, electrical stimulation of muscles, or other attempts to regain motor power early

Sister Elizabeth Kenny, an Australian nurse, for many years has used hot fomentations applied over the entire body This is intended to relax muscle spasm and is said to relieve pain With the disappearance of pain and spasm guarded motion is begun This method of treatment may cut down materially the length of the acute stage of the disease It may quite possibly make the patient more comfortable It is difficult to see how this treatment can in any way affect muscles whose nerve supply has been destroyed with death of the nerve cells in the spinal cord during the course of the disease The method should be given a thorough trial so that its benefits and limitations may be fully understood

[The following quotation from 'The Kenny Method of Treatment for Infantile Paralysis," by W H Cole, J F Pohl, and M E Knapp, in Archives of Physical Therapy, 23 7, 399 epitomizes the rationale upon which the Kenny method is based The article cited is Publication No 40 of the National Foundation for Infantile Paralysis, Inc It discusses the treatment in considerable detail, and can be secured by any doctor by writing for it to The National Foundation for Infantile Paralysis, Inc , 120 Broadway New York City It is essentially a manual for the carrying out of the treatment

This manual is not to replace either special training in the work or the book which Miss Kenny has herself published neither does it attempt to analyze critically the theory of the method nor to modify in any way the method itself It is merely an attempt to clarify and simplify in the light of personal observation and experience what she has written about the technic The various steps and procedures have not been changed, and Miss Kenny s terminology has been retained Many of the terms are not scientifically accurate as understood by physicians, but they do describe conditions which are present

Nothing occult is involved in her methods but it does demand an intimate knowledge of muscle anatomy, the neuromuscular system, and much attention to detail in re education The principles can be quickly learned by the physician but the technical practice of the method requires mastery of many details if satisfactory results are to be obtained Just who is best qualified to do this is probably debatable but certainly, graduate nurses and registered physical therapy technicians are the two groups from which most of the workers should come

The treatment must be begun as soon as the case is diagnosed if it is to be most efficient this means that treatment must begin in the acute stage during the period of quarantine Each hospital will have to develop a routine devised to make the maximum use of its available skilled personnel Certainly the most difficult part of the treatment from the physical point of view, the application of hot packs, can be efficiently carried out by intelligent attendants or orderlies after a short training period *Always, however, the treatment must be supervised and checked by the physician in charge of the case* Certainly the re education of disabled muscles can be done only by technicians with the highest skills and abilities

Symptomatology

The concept of infantile paralysis on which Miss Kennys treatment is based is fundamentally different from that heretofore pre-

vailing The disease in the acute stage affects not only the anterior horn cells but also adjacent portions of the cord It may be segmental in character, involving the central nervous system including the sympathetic system in general so that symptoms other than those due only to involvement of the anterior horn cells must be present The symptoms, as pointed out by Miss Kenny and as observed by us are mainly

1 The muscles affected present the condition of spasm
2 The affected muscles become shortened
3 Coordination is disorganized and incoordination frequently seen
4 The patient frequently loses power in non affected muscles because affected muscles are pulling the non affected muscles from their normal resting place and retaining them in this lengthened position through the unrelaxed spasm in the affected group
5 The non affected muscles frequently refuse to contract due to "mental alienation"

These *symptoms* may be *condensed* into three factors which distinguish the Kenny concept of infantile paralysis

1 Muscle spasm
2 Incoordination
3 "Mental alienation"

In an exceedingly severe infection enough anterior horn cells are destroyed at the outset to cause complete flaccid paralysis of certain muscles or parts, and spasm, if present at all, may be fleeting in these cases Treatment for this condition is ineffective in preventing the paralysis

The treatment, then, is not designed to prevent paralysis and has no influence on the neurologic damage inflicted by the disease It is designed to minimize the effects of the disease in terms of residual disability and deformity requiring surgical treatment, and to materially shorten the convalescent stage

The Kenny treatment, or any other form of treatment, in the acute stage of the disease may be regarded as 'medical treatment Regardless of the term used to describe it, the handling of the acute phase of the disease should be of major importance to the man who has to handle the late results, since his task may be much simplified, and his results be much better, if optimum primary "medical' treatment is accorded the patient —Ed]

In all instances of paralysis the stronger muscles will overpull the weaker Gravity also operates to overpull weakened muscles As a result of those two factors deformity will ensue unless measures are taken to prevent it During this acute stage it is advisable to protect any weakened muscles with plaster of paris splints If one or the other or both lower extremities are involved a plaster of paris spica should be applied with legs held straight and the feet held at 90° to the long axis of the leg Since the deltoid muscle is the most frequently involved of those in the upper extremity a plaster of paris spica may be applied to prevent stretching of the damaged muscle by gravity If light metal splints are available, they may be used instead of the plaster of paris Recumbency on a fracture bed should be rigidly adhered to The most distressing and dangerous form of muscle weakness is that involving the diaphragm In patients showing this symptom the prognosis is poor even if they survive the first onslaught of the disease, since they are prone to succumb to simple respiratory infections The 'iron lung or respirator may tide over those patients with temporary paralysis and it has been the only means of keeping some of them alive

The Convalescent Stage

This stage of the disease is of variable length It begins with the disappearance of muscle soreness and lasts until all improvement in muscle power has ceased Great vigilance is still required No damaged muscle will ever achieve the maximum recovery possible if it is allowed to be stretched or fatigued Therefore, protection against a stronger opponent muscle and the effects of gravity must be provided Rest and appropriate braces are the essential requisites of treatment of this stage of the disease It is only by meticulous attention to detail that numerous deformities, such as flexion

at the knee or hip, may be prevented or minimized Prolonged bed rest may still be essential The sitting posture will tend to produce flexion deformity at the hip and knee if there is extensor weakness

Weakness of Abdominal and Spinal Muscles If there is evident weakness of the abdominal or spinal muscles, support must be provided by a corset, brace, or plaster of paris jacket

There are various forms of physical therapy which may be employed with benefit during this convalescent stage It may be stated that McCarroll and Crego of St Louis have recently reported in a rather sizable series of patients with anterior poliomyelitis that early treatment of any sort after the acute stage has little or no effect on the course of the disease and altees the degree of residual paralysis to little or no extent The extent of paralysis depends upon the original anterior horn cell destruction This view is held by many surgeons but is disputed by the advocates of physical therapeutic measures

1 Massage This is generally accorded first place It improves the circulation to the affected part, but rough mauling or manipulation of paralyzed muscles must be rigidly avoided

2 Heat This is advocated as another effective means of increasing blood supply to weakened or paralyzed muscles It should be moderate in degree over a prolonged period of time rather than intense for a short period of time

3 Exercises Under Water This measure is generally acknowledged to be of great value during this stage of the disease The buoyancy of the water minimizes the effort required of weakened muscles to perform their function A bathtub will suffice, but a warm swimming pool is better If exercise under or in water can be supplemented with massage, the patient will receive the optimum form of physical therapy

4 Electrical Stimulation of Muscles The benefits to paralyzed or weakened muscles of this form of physical therapy are decidedly open to question The advocates of its use are apt to be physical therapists

5 Muscle Training or Re education This is defined as "an attempt to restore a cerebral motor impulse to a muscle" If the lower motor neurone is destroyed it is utterly impossible of accomplishment, and it is the writer s firm belief that an unconscionable amount of time and effort may be wasted at great expense, for a gain in motor power which may be quite negligible If the paralysis is of a temporary nature, motor power will return, and exercise, under supervision, of the involved muscles may increase their function and perhaps hasten their recovery, provided there is adequate protection afforded against stretching and fatigue during these exercise periods The exercise of any given set of muscles should never be through a full arc of motion nor against gravity to begin with As power increases, protection against gravity may be utilized and actual resistance to muscle pull may be afforded

If the physiologic motor action of any given set of muscles is understood, the proper exercises follow almost automatically, as night the day For instance, let us consider the two groups of muscles which control the knee joint

I IF THE HAMSTRING OR FLEXOR MUSCLES OF THE KNEE JOINT ARE PARALYZED OR WEAK, EXERCISES MAY BE CONDUCTED AS FOLLOWS

1 Gravity Eliminated The patient lies on the affected side with the hip flexed, leg straight, the opposite thigh held by person supervising the exercises (a) Flex knee with assistance, (b) flex knee without assistance, (c) flex knee against resistance

2 Against Gravity The patient lies face downward, leg straight (a) Flex knee with assistance, (b) flex knee without assistance, (c) flex knee against resistance

3 With Gravity The patient lies on his back, thigh is flexed at 90° Patient flexes knee against slight resistance

II IF THE QUADRICEPS FEMORIS OR EXTEN

SOR MUSCLES OF THE KNEE JOINT ARE PARALYZED OR WEAK

1 *Gravity Eliminated* The patient lies on the affected side with knee flexed (a) Extend knee with assistance, (b) extend knee without assistance (c) extend knee against resistance

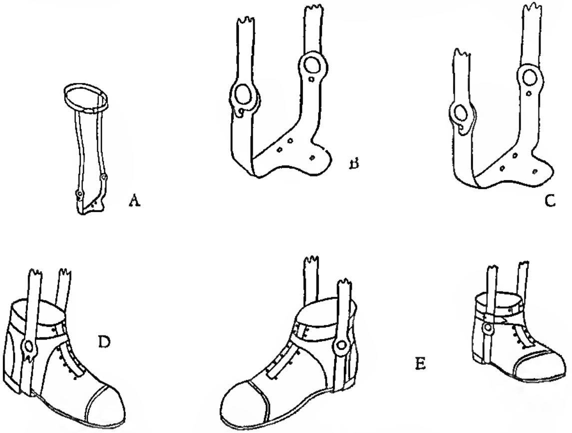


Fig 207 An ankle brace (*A*) *Construction of brace with foot piece to be attached* to shoe by three screws (B) Joint with posterior catch to prevent footdrop (C) Anterior catch to retard calcaneus (D) Ankle brace with double catch for limited motion with outside T strap (E) Ankle brace with free motion, inside T strap and manner in which it fastens over the outer bar

2 *Against Gravity* The patient sits on a table or chair with knee flexed (a) Extend knee with assistance, (b) extend knee without assistance, (c) extend knee against resistance

3 *With Gravity* The patient lies on his face with knee flexed Extend the knee against slight resistance

For the reader who is anxious to go more deeply into the subject of muscle training there are many and various methods available A small reference list will be found in the Bibliography

Warm Clothes It is essential to remember that these patients with damaged muscles due to anterior poliomyelitis are extremely sensitive to cold Chilblains and even trophic ulcers result from frostbite during the winter months They should, if they live in regions of severe cold, be instructed to wear warm clothing, woolen stockings or socks, and woolen underwear if necessary

Braces These are used extensively during the convalescent stage of the disease, and their use is often carried over into the final or residual stage These are usually made of steel of a gauge varying with the age and weight of the patient Duralumin is

considerably lighter than steel but does not stand the constant daily abuse as well The function of a brace is to prevent deformity, if possible and to offer support to those portions of the body whose normal muscular support has been withdrawn due to weakness or paralysis of the muscles affecting that part With the help of braces many paralytics who otherwise would be confined to bed or chair are enabled to walk For the most part braces are temporary expedients and if their use may be dispensed with later by surgery this step should be urged Braces are expensive they break and are frequently outgrown in children By their use, the dependent situation of the wearer is constantly emphasized The simpler and more frequently used braces are as follows

1 Ankle Brace (Fig 207) This brace consists of two steel uprights hinged at the ankle to a foot plate which fastens to the shoe At the top of the calf there is a posterior curved metal band connecting the two steel bars This band a little less than half a circle is closed in front by a strap and buckle The hinge at the ankle is controlled by catches as follows

a A posterior catch to prevent footdrop

b An anterior catch to prevent or retard calcaneus gait

c An anterior and posterior catch to insure limited motion in a foot that has little or no power

d Occasionally but rarely no catch is used and free motion is allowed at the ankle

Lateral motion in the foot may be controlled by means of a broad T strap fastened to the side of the shoe and strapped to the opposite steel bar A valgus foot requires an inside T strap and a varus foot an outside T strap

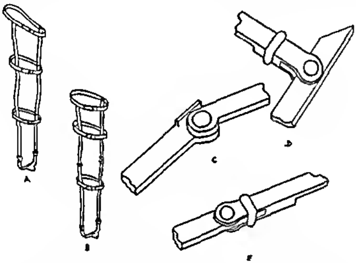


Fig 208 A long leg brace (A) With no knee joint (B) With a ringlock catch at knee (C) Detail view of construction of joint at knee (D) Ringlock catch unlocked in flexion (E) Ringlock catch at knee unlocked in extension

2 Long Leg Brace (Fig 208) This is used for weakness or paralysis of the quadriceps femoris or hamstrings or both and it is used to stabilize the knee joint in walking It consists of two long steel uprights extended from an ankle brace beyond the knee to the upper thigh There is a posterior curved band of steel joining these uprights at the calf, at the midthigh and at the top of the brace A strap and buckle or a laced leather cuff fastens these bands in front at the calf and thigh and at the top the band is closed in front by a strap and buckle

This brace may be constructed with no knee joint at but little expense If the patient wants to bend the knee in sitting a ring lock or drop-catch joint is constructed which readily locks when the knee is in extension and may be released to allow flexion

3 LONG LEG BRACE WITH PELVIC BAND (Fig 209) If there is marked instability at the hip joint and abductor weakness additional stability is gained by adding a pelvic band with a joint attached to the outer of the two bars on the long leg brace

4 DOUBLE LONG LEG BRACE (Figs 210 and 211) This with limited motion at the ankle *ringlock at the knees a pelvic band* and a Knight corset attached will allow the occasional patient who is completely paralyzed below the umbilicus level to do tripod walking with crutches

5 TAYLOR OR KNIGHT CORSET BRACE (Figs 212 and 213) This may be used to support the spine, but both are ineffective in preventing in any sense a lateral curvature of the spine due to anterior poliomyelitis They will however aid in supporting weak abdominal muscles by means of their aprons

6 ABDUCTION ARM SPLINT OR PLATFORM SPLINT (Fig 214) This is the most commonly used brace in upper extremity paralysis involving the deltoid muscle It consists of an upright bar applied to the side of the body by two metal bands with straps and buckles passing around the thorax and just above the iliac crests The upright is bent at 90° on itself at the shoulder and supports the arm and forearm by two straps for each There is a slight cock up rest for the hand with a strap The elbow has a free joint

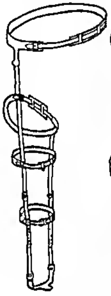


FIG 209

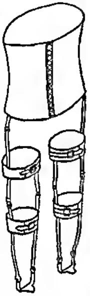


FIG 210

FIG 211

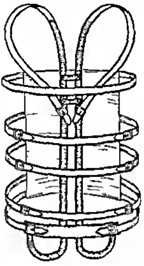
FIG 209 A long leg brace with pelvic band showing limited motion at ankle ringlock at knee joint and free extension and flexion at hip

FIG 210 Double long leg brace with Knight corset attached to pelvic band In some instances a catch to prevent unlimited motion will have to be applied at hip joint of one side

FIG 211 Patient with a complete paralysis below level of umbilicus able to stand and walk with aid of double stiff leg braces with pelvic band and crutches This child originally had a Knight corset attached to top of pelvic band This is the so called tripod walker

The Residual or Chronic Stage

The residual or chronic stage of anterior poliomyelitis is reached when improvement in motor power of the paralyzed muscles has ceased This improvement in function with proper treatment may be expected to take place within a period of two years, but most of it occurs during the first year When this residual stage is reached it is time care fully to take stock of the situation The extent of the damage must be estimated, as well as its effect on the patient Fortunately by this time a large percentage of the victims of this disease will have been completely rehabilitated, others will have such minor disabilities that they will require no further treatment However, there will remain a sizable residuum of cripples whose rehabilitation will tax the surgeon s ingenuity At this point it is well to recall certain fundamental facts of anatomy and physiology before plunging into the rescue work



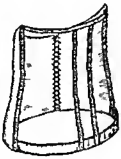


Fig 212 (*Left*) Taylor Spinal assistant Two bars of steel a short pelvic band and straps over shoulders, fastened to an apron in front which supports abdominal muscles

Fig 213 (*Right*) Knight spinal corset consisting of a steel pelvic band two inches wide and two lateral uprights attaching this band to a middorsal steel band and fastened in front by a corset which laces in the midline

1 **Function of Upper Extremity** The upper extremity, suspended from the shoulder girdle, is held away from the side of the body Its main function is to perform a wide and varying range of motion to serve the tactile and prehensile fingers The chief characteristic of this upper extremity is mobility In following this conception it will at once be seen that if the muscles controlling the hand and fingers are hopelessly paralyzed, it is utterly foolish to attempt any reconstructive surgery at the shoulder or elbow joints

2 **Function of Lower Extremity** The pelvic girdle is massive and closely attached to the trunk with little motion in the sacroiliac joints The hip joint is deeply socketed and surrounded by strong muscles, while the remaining joints of the lower extremity are large and strong for stability in weight bearing. The chief characteristic of the lower extremity is stability This principle of stability rather than fine coordinated movements of muscle groups should be borne in mind in selecting the proper surgical procedure in patients with anterior

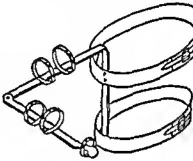


Fig 214 Abduction arm splint or platform splint which consists of a steel upright applied to side of body by steel bars just above pelvis and around thorax fastened by buckles and straps Upright is bent on itself at 90° at shoulder joint Elbow joint has free motion and band is held in slight cock up position

poliomyelitis involving the lower extremity

3 Extending between these two shoulder girdles and upper extremities and the two pelvic girdles and lower extremities there is as a connecting link the vertebral column, a complicated series of bones and joints whose upright posture depends upon the balanced action of an amazingly intricate set of intrinsic muscles Paralysis or marked weakening of one set of these muscles or of the abdominal muscles leads to that bizarre and at times baffling deformity of the spine —lateral curvature or scoliosis

OPERATIVE TREATMENT OF ANTERIOR POLIOMYELITIS

The operative treatment of this disease is reserved for the residual stage after all improvement by other means has been accomplished Surgery may be used to alleviate the situation of these cripples in the following ways (1) By improvement of function, (2) by decrease of deformity and (3) by increase of stability No operative treatment should be undertaken unless there is reasonable certainty of improving the patient s situation At times patients are seen who are so hopelessly and helplessly paralyzed that any expectation of improving their lot by surgical means is fantastic Above any technical skill in various operative procedures there must be ranked the *judgment of the surgeon who by experience* will know how to select his patients study the situation and with care choose that particular procedure fitted to this patient s needs Here as elsewhere in surgery, the surgeon stands head and shoulders above the operator

Operations to Improve Function

1 Among those *surgical* procedures designed to improve function of muscles paralyzed as a result of anterior poliomyelitis transplantation of nerves has been tried and has not met with sufficient success to allow recommendation of its use

2 The transplantation or transference of tendons of unparalyzed muscles to allow them to assume the work of paralyzed mu cles *has been* practiced *extensively In c* paring the function of the upper extre where a wide range of motion i re to the lower extremity where stabili prime requisite one might on super consideration think that there woul l larger field of usefulness for tendon tra plantation in paralyses of the upper extre ity and that the field would be relativ l limited in those paralyses involving the lower extremity However this is not the case the reverse is true Tendon transference is employed far more frequently in *the lower extremity paralyses The reason* for this is that the finely coordinated movements of the upper extremity especially the hand and fingers usually cannot be substituted for with any marked success

Tendon transference is performed for three purposes

1 To improve function It must be borne in mind that seldom in cases where tendon transference may he indicated are the so called unparalyzed muscles unscathed and often a weakened muscle is wrongly transferred and is expected to take over under new *leverage* a job that *it is quite* incapable of assuming

2 To remove a persisting deforming factor There is but little question that the *persisting deforming pull of an unparalyzed* muscle should be neutralized by redirecting its force into a useful channel Failure to observe this rule has wrecked many a well conceived stabilization operation on the foot

3 To remedy static imbalance It is very doubtful if tendon transference of itself will adequately restore balance Tendon transference in addition to a stabilizing procedure *with the emphasis on the latter,* is the most effective procedure

Operations to Decrease Deformity

Those operations which *decrease* or relieve deformity are typified by (1) posterior

capsulotomy at the knee joint to relieve flexion deformity of that joint (2) transference of the muscles from the iliac crest to correct hip flexion deformity or (3) supracondylar osteotomy of the femur for correction of torsion of the femoral shaft

Operations to Increase Stability

Those operations which improve function by stabilization of joints whose musculature is paralyzed are by all odds the most useful and most widely practiced in the surgical treatment of anterior poliomyelitis There are numerous procedures many varying only in small technical details In principle they are alike in striving to obtain useful weight bearing by gain of stability with sacrifice of motion

SURGICAL TREATMENT OF UPPER EXTREMITY LESIONS DUE TO ANTERIOR POLIOMYELITIS

Of those patients who develop paralysis due to anterior poliomyelitis only a little over 30 per cent show evidence of paralysis or weakness of the upper extremity while over 80 per cent present evidence of paralysis or weakness of the lower extremity It is indeed fortunate that the upper extremities of these patients are so frequently spared as surgical treatment of the complicated hand arm mechanism is on the whole not particularly satisfactory

Shoulder

Paralysis of the deltoid muscle is common among upper extremity lesions Unless there is a reasonably strong hand and forearm it is quite useless to consider operative work at the shoulder and unless there is strong active function in the trapezius rhomboids and serratus anterior no operative work can be successfully undertaken

Tendon transference procedures to replace the paralyzed deltoid muscle have been described by Mayer Ober and others The fact that there is but little acceptance of these procedures raises a question of their efficacy The one which seems to offer some chance of success is that described by Ober

Transference of Short Head of Biceps and Long Head of Triceps to Acromion Process (Ober) This is of course feasible only if these muscles are strong A curved incision is made over the shoulder The coracoid process is exposed and the short head of the biceps and a portion of its bony attachment detached dissecting the muscle free to the entrance of the musculocutaneous nerve Through the posterior end of the incision the long head of the triceps is also exposed and removed from its origin with a small piece of bone This muscle must then be dissected free from the upper fourth of the humerus carefully preserving the nerve supply The tip of the acromion process is exposed and divided longitudinally with an osteotome The free end of the triceps is carried over the deltoid mu cle and sutured into the posterior aspect of the cleft in the acromion process while the short head of the biceps is sutured into the anterior aspect of the cleft Each tendon and its bony attachment are sutured in place with silk and if possible the two ends are sutured together After closure of the wound the arm is held in abduction in a plaster of paris spica which may be bivalved at three weeks after operation and a little active motion allowed At approximately six weeks after operation the spica may be removed and relaxed exercises may be allowed A platform abduction splint may be worn part time for several additional weeks if necessary

Arthrodesis of Shoulder Joint (Figs 215 and 216) With a good hand and forearm and adequate musculature to control the scapula this procedure will convert an otherwise useless shoulder joint into a useful stable mechanism to serve the hand and fingers

There are a number of ways of obtaining arthrodesis of the shoulder joint but in our experience the most effective is an operation

of the claw hammer type The shoulder joint is exposed through a curved incision The deltoid muscle is divided just distal to its origin The capsule of the joint is then excised and articular cartilage is removed from the head of the humerus and the glenoid fossa The under surface of the acromion process is roughened with a gouge or chisel after the periosteum has been stripped away The humeral head is then placed in contact with the glenoid and the acromion process with the arm abducted at about 80° and protracted 20° beyond neutral position Fixation is then obtained by inserting one or two vitallium screws through the acromion process deeply into the humerus through the head to the shaft The deltoid muscle is sutured and the skin is closed A plaster of paris spica is applied and worn for 10 to 12 weeks After two weeks this splint may be bivalved, sutures removed, and massage given Active motion in the splint may be started at six to eight weeks after operation (For other shoulder arthrodesis technic see Chapter 15)

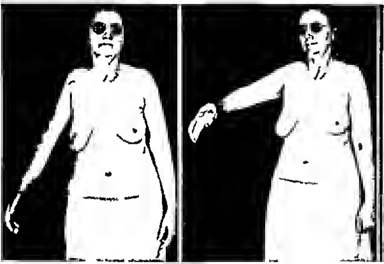


Fig 215

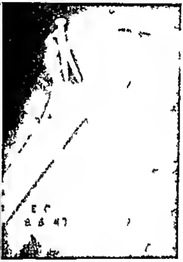


Fig 216

Fig 215 A patient with complete deltoid paralysis Arthrodesis of shoulder joint performed May 1939 Photographs six months later showing ability to raise arm from side of body Patient subsequently had a wrist fusion performed

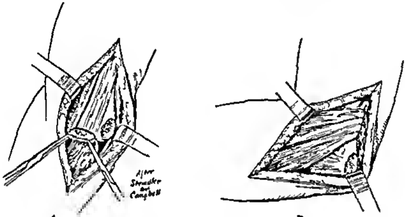
Fig 216 Postoperative roentgenograms of patient with shoulder fusion Humerus is fixed at an angle of approximately 70° with scapula

Elbow Joint

Operative work at the elbow joint where there is paralysis due to anterior poliomyelitis is not very practical for the most part and of course never justified unless there is a good hand With paralysis of the triceps brachii muscle gravity will always act to extend the forearm For paralysis of the flexors of the elbow joint a distressing disability, Steindler has devised a muscle transference operation which may be helpful in a few carefully selected cases

Transference of Common Flexor Origin to Humerus (Steindler and Campbell) (Fig 217) A curved incision is made over the lower third of the arm and the upper third of the forearm on the ulnar side following the course of the pronator radii teres at its lower end The ulnar nerve is localized and retracted posteriorly The common origin of the pronator teres and the flexor muscle group is exposed and dissected free At this point Campbell has modified the procedure by removing a small segment of bone from the medial humeral condyle

to which these muscles are attached (This should be done since any tendon transference is better accomplished if it can be anchored by bone to bone contact) The muscles are then freed distally for 1½ inches and, with the elbow flexed, the bone-muscle origin is inserted into the humeral shaft two inches above the medial condyle by sutures passed through drill holes After closure of the wound, the elbow is immobilized by a circular plaster of paris splint in acute flexion with the forearm in neutral position between pronation and supination After two weeks a splint is employed to keep the forearm in flexion while physical therapy and active motion are commenced



A B

Fig 217 Transplantation of common flexor origin from medial epicondyle of humerus to shaft of humerus (A) Common origin of flexor muscles of forearm with small piece of bone from medial humeral epicondyle (B) Common flexor origin with bony attachment transplanted into medial border of shaft of humerus approximately two inches proximal to medial epicondyle

A posterior bone block operation at the elbow has been devised by Putti to limit extension at 90° and thereby increase stability This might be useful in a flail elbow in which the flexor muscle transference to the humerus had been done [This is done in one of three ways The posterior aspect of the lower humerus and the olecranon are exposed preferably through a posterolateral incision The posterior face of the humeral articular surface is split off by a thin osteotome held transversely and driven from below upward to make a thin broad flap remaining attached at its upper end The split is wedged open, and packed with bone chips so that the backwardly wedged posterior flap effectively blocks extension beyond 90° by impingement against the olecranon Eight to 12 weeks' postoperative immobilization in plaster in the right angled position follows, after which gradual resumption of function is practiced

Instead of the above procedure, the posterior condylar surface just above the olecranon, with the elbow at 90°, can be split by an osteotome held transversely and driven from behind forward and a graft inserted into the split to form a shelf preventing extension by impingement on the olecranon at 90°

A third alternative is to drive an osteotome into the olecranon with the elbow at right angles, the osteotome paralleling the posterior aspect of the humerus and being driven from the upper edge of the olecranon articular surface through the upper end of the bone toward the posterior aspect of the

olecranon In the split so made is placed a *flat graft which projects directly up behind* the humerus and prevents extension by impingement against posterior aspect of humerus

The first of these procedures is generally considered preferable —Ed]

Operative fusion of the elbow joint which is flail offers but little solution to the problem except in rare instances (For technic of elbow fusion see Chapter 15)

transference may be done only in an occasional case The intricate movements of the hand and fingers cannot often be replaced by surgery

Fixed pronation of the forearm due to an imbalance between pronators and supinators at times requires operative intervention For this condition Tubby devised a tendon transference operation

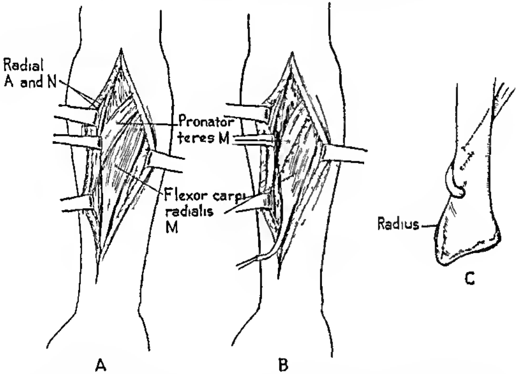


Fig 218 Transplantation of pronator teres and flexor carpi radialis into shaft of *radius for fixed pronation (A) Incision exposing pronator radii teres and flexor carpi* radialis muscles (B) Shows freed pronator radii teres muscle belly sutured to flexor carpi radialis whose tendon has been divided approximately 1½ inches proximal to wrist joint (C) Shows combined tendon behind radius where it emerges at lateral border and inserts into a drill hole in radius from before backward and is then sutured to itself

Forearm, Wrist Joint, and Hands

In paralysis of the muscles of the forearm involving loss of the use of the hand *and fingers*, surgery has *decided limitations* The muscles paralyzed are often numerous and those which have escaped complete paralysis are so often weakened that *tendon*

Transference of Pronator Teres and Flexor Carpi Radialis for Paralysis of Supinator Muscles (Tubby) (Fig 218) *An incision is made over the volar forearm* region approximately six inches long following the course of the radial artery The *flexor carpi radialis is isolated from the* brachioradialis The radial vessels and nerve are identified and retracted laterally The *pronator radii teres is dissected to its in*

sertion and the tendon with its adjacent periosteum is detached from the radius The flexor carpi radialis is dissected free and divided approximately 1½ inches above the wrist joint The two muscles, under tension are sutured together The interosseous membrane is divided close to the radius, preserving the interosseous nerve

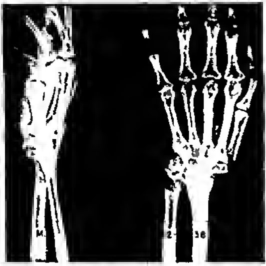


Fig 219 Roentgenogram of wrist joint two years after arthrodesis of wrist joint to overcome wristdrop This wrist is arthrodesed at approximately 30° of dorsiflexion which is a very useful position Perhaps 5 or 10° more dorsiflexion would be even better

and artery The conjoined tendon is then passed through the interosseous membrane around the radius and inserted from before backward into a drill hole in the radius and sutured to itself Mayer has suggested a modification of this technic by passing the conjoined tendon subcutaneously around the inner border of the forearm across the dorsal surface to insert into a drill hole in the radius two inches proximal to the wrist joint

After closure of the wound, a circular plaster of paris splint is applied with the elbow flexed at 90° and the forearm in full supination This is removed two to three weeks after operation and physical therapy and active motion is instituted Until active supination returns, a splint should be worn

Wristdrop Due to Paralysis of Extensors of Wrist For wristdrop due to anterior poliomyelitis with limited flexor power, which is the usual situation, a fusion or arthrodesis of the wrist joint is by all odds the most useful procedure It holds the hand in 35 to 40° of dorsiflexion, which is the grasping position, and allows what little power there may be in the flexor muscles to be utilized

Arthrodesis or Fusion of Wrist Joint (Fig 219) A longitudinal incision approximately four inches in length is made over the dorsal surface of the wrist, slightly toward the radial side This is deepened to the bony structures retracting the tendons medially and laterally The radiocarpal, intercarpal and carpometacarpal joints are exposed With small sharp chisels and curettes the cartilage is removed from all articular surfaces except the carpometacarpal joint of the thumb When this is completed a graft from the adjacent exposed radius is removed and fitted from a slot in the radius across the carpus into a slot in the base of the second and third metacarpal bones The wrist is held in extension at a 35 to 40° angle to the long axis of the forearm by a circular plaster-of paris splint, which should extend from above the elbow, which is flexed, to the proximal end of the fingers This should be bivalved, and after 10 days it should be replaced with a second snug similar plaster splint to be worn for 10 to 12 weeks (For other wrist joint fusion technic see Chapters 14 and 15)

Occasionally the muscles supplied by the radial nerve are paralyzed while those supplied by the ulnar and median nerves are relatively unimpaired In such an instance the transference of certain flexor muscles may be used to substitute for the lost extensors

Transference of Flexor Carpi Ulnaris and Flexor Carpi Radialis into Extensor Tendons at Wrist (Jones Billington)

(Fig 220) An incision 1½ inches long is made over the radial border of the forearm at the insertion of the pronator radii teres A second incision approximately one inch in length is made to expose the tendon of the flexor carpi radialis muscle three inches of the thumb and fingers are now exposed

Through the first incision the pronator radii teres is detached from its radial insertion and passed through small openings in the tendons of the extensor carpi radialis longus and brevis muscles These openings

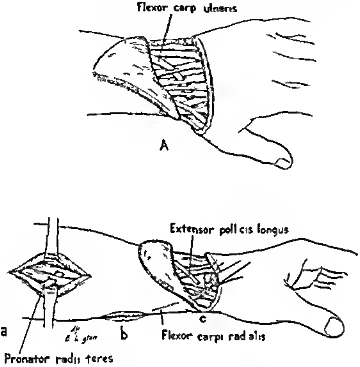


Fig 220 Transference of flexor carpi ulnaris, pronator radii teres, and flexor carpi radialis to overcome wristdrop (A) Shows exposed extensor tendons at dorsal surface of wrist with flexor carpi ulnaris tendon inserted into extensor tendons of fifth, fourth, third, and second fingers, and sutured (B) Shows (a) transference of tendon of pronator radii teres into tendons of extensor carpi radialis longus and brevis, and (b) incision through which *flexor carpi radialis tendon is exposed three* inches proximal to wrist joint (c) Shows flexor carpi radialis rerouted to dorsal surface of wrist, sutured to abductor pollicis and extensor pollicis brevis, and finally end to end to extensor pollicis longus

proximal to the wrist joint The third incision is carried along the ulnar border of the forearm from a point four inches proximal to the pisiform bone to that bone, and then across the dorsum of the wrist at a right angle to the base of the first metacarpal bone At this time extensor tendons and the inserted tendon are sutured under some tension, with the wrist held in dorsiflexion

The flexor carpi ulnaris muscle is divided at its insertion and all muscle fibers are dissected free from the tendon for a distance of two to three inches above its in

sertion This tendon is passed subcutaneously across the dorsum of the wrist and then through small openings in the extensor tendons of the fifth fourth third, and second fingers and sutured to each under some tension, with the wrist in full dorsiflexion

Through the retracted extreme radial end of the large third incision the flexor carpi radialis muscle is identified and divided at tendon After suture of the wound the wrist is held in hyperextension with fingers and thumb extended by a splint for two or three weeks After this the splint is removed daily and guarded active motion is allowed After four weeks physical therapy may be employed, but the splint should be worn between exercise periods for several additional weeks

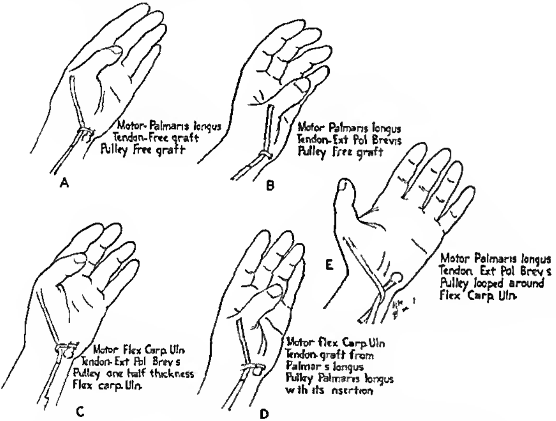


Fig 221 These drawings from Bunnell's Surgery of the Hand (Lippincott) show a number of possible substitution operations that may be performed to replace loss of opponens pollicis (C) Illustrates operation described in text

its insertion It is then drawn into the second incision and redirected subcutaneously to the dorsum of the wrist joint at the radial styloid process The tendon is then passed through small openings in the tendons of the abductor pollicis and extensor pollicis brevis and sutured to each under tension The extensor pollicis longus tendon is then divided and its distal portion is sutured to the distal end of the flexor carpi radialis

Tendon Transference for Paralysis of Opponens Muscle of Thumb (Fig 221) The loss of power to oppose the thumb leaves a hand that is severely handicapped This situation occasionally is encountered in patients with residual anterior poliomyelitis and at times the means are at hand to remedy the situation surgically Steindler has devised a technic utilizing the radial half of the flexor longus pollicis, redirecting

it to act as an opposing motor unit Bunnell has offered a variety of procedures to take care of varying situations which may be encountered (Fig 221) He states that for efficacious transference of a new opponens motor unit to the thumb the tendon (1) must be inserted into the dorso ulnar aspect of the base of the proximal phalanx of the thumb and (2) must pass from this insertion subcutaneously in a direct line to the pisiform bone where a tendon pulley is provided

1 For Motor Power Any of the following muscles may be employed The flexor carpi ulnaris palmaris longus flexor digitorum sublimis to the ring finger or any other available long flexor muscle

2 For Transmission of Power For transmission of power of any of the above muscles to its proper insertion the extensor pollicis brevis muscle is at hand and is ideal

3 For Construction of a Pulley at the Pisiform Bone For this a free tendon graft may be utilized attaching it through the short muscles and tendons at the pisiform bone The radial half of the flexor carpi ulnaris may be utilized by splitting this tendon and using half its distal thickness as the pulley or the motor unit may be looped around the distal part of the tendon of the flexor carpi ulnaris

The operation of choice (providing the flexor carpi ulnaris has strong active power) is as follows (Bunnell) (Fig 221 C) A transverse incision is made at the distal volar flexion crease of the wrist from the midline to the ulnar border and then continued upward at a right angle proximally for a distance of 2½ to 3 inches The flexor carpi ulnaris tendon is exposed and split in half longitudinally from the pisiform bone for a distance of two inches proximally The radial half is divided transversely at the proximal end of the split and the ulnar half is divided at its insertion The pulley is constructed by suture of the radial half of the tendon to itself and to the ligaments attaching to the pisiform bone A second incision 1 to 1½ inches long is made longitudinally over the radial side of the thumb at the metacarpophalangeal joint exposing the extensor pollicis brevis tendon A third longitudinal incision two to three inches in length is made over the radial and dorsal border of the forearm just proximal to the wrist joint The extensor pollicis brevis tendon is identified and divided as far proximally as possible The divided tendon is then withdrawn into the second incision and passed subcutaneously over the thenar eminence into the first incision The free end of this extensor pollicis brevis tendon is drawn through the previously constructed pulley and with the thumb in full opposition it is sutured to the distal end of the divided flexor carpi ulnaris tendon under slight tension All incisions are closed with silk The thumb is held in full opposition adduction and slight flexion for three weeks with either a plaster of paris bandage or adhesive plaster After this motion is allowed

For various other technics Bunnell's original article should be consulted (Fig 221)

SURGICAL TREATMENT OF LOWER EXTREMITY LESIONS DUE TO ANTERIOR POLIOMYELITIS

Hip Joint

The disabilities due to paralysis and the deformity due to unopposed muscle pull at the hip joint are commonly encountered in residual anterior poliomyelitis Of these the most frequently seen is flexion deformity which causes a characteristic forward lurch in walking If it is bilateral compensation may be obtained by an extreme lumbar lordosis but in some instances it may be so severe as to make locomotion possible only in the quadruped position

The muscles responsible for hip-flexion deformity are most frequently the sartorius tensor fasciae latae and anterior portions

of the glutei At times the psoas and the capsule of the hip joint may be contracted

In our experience a Soutter operation with slight modification gives the most satisfactory result in treatment of this flexion deformity

the acetabulum The thigh is then extended, and if there is still marked resistance the psoas and rectus femoris tendons and even the capsule of the hip joint may have to be divided After this the thigh can usually be fully extended A plaster-of paris spica is

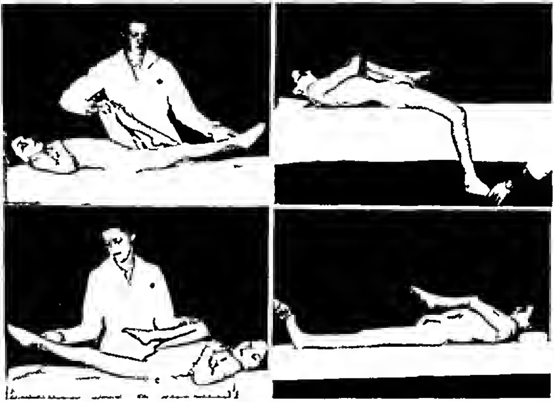


Fig 222 Hip-flexion deformity (*Left*) Photographs of a child to show bilateral hip-flexion deformity before operative release (*Right*) Photographs of another child six years after release of hip flexion deformity showing absence of deformity These photographs demonstrate means of showing presence and absence of hip flexion

Release of Hip flexion Deformity (Fig 222) An incision is made from the upper thigh to the anterior superior spine and continued posteriorly along the iliac crest for a distance of three inches The total length of the incision varies with the size of the patient but its midpoint is at the anterior superior spine The tensor fasciae latae and anterior gluteal muscles are separated sharply from the bone of the iliac crest and then dissected subperiosteally from the dorsum of the ilium with a periosteal elevator down to a point just above

applied with the thigh in hyperextension but with no abduction This position must be maintained for six to eight weeks A warning has been issued against immediate postoperative hyperextension of the thigh in these patients on account of danger of interfering with the lumen of the femoral artery and of untoward abdominal symptoms We have not encountered any such complications but it is always well to meticulously observe the circulation of the toes in any patient with a circular plaster splint

The Unstable Hip Joint. In patients

with paralysis of the gluteus maximus muscle with active hip flexors producing some flexion deformity, it is not unusual to encounter subluxation or actual dislocation of the hip joint Such a joint may be stabilized by various types of shelf operations

Shelf Operation for Hip Stabilization (Fig 223) (This is a slight modification of the technic described by Lowman) Through an incision from the upper thigh to the iliac crest and continued posteriorly three to four inches the ilium is exposed subperiosteally as far as the acetabulum Unless it is actually necessary to reduce a dislocation the capsule of the joint is not opened On the dorsum of the ilium three leaves of bone are outlined with an osteotome A small drill hole is placed in the upper center of each These leaves are then separated from the ilium down to the acetabular margin Each leaf consists of about one half the thickness of the ilium They are then turned down over the head and neck of the femur and sutured to the capsule by silk sutures which are passed through the various drill holes A mass of bone chips from the ilium is added as re enforcement at the attached bases of the leaves of bone After closure of the wound a plaster of paris spica is applied and worn for 10 weeks After four weeks the patient may become ambulatory with crutches (Figs 224 and 225) (For other technics in shelf operations see Chapter 15)

Arthrodesis of Hip Joint To compensate for the unsightly limp and instability of paralysis of the gluteus maximus and medius muscles a number of muscle substitution operations have been devised However, for this condition and for the flail hip an arthrodesis of the hip joint is at times the only effective means of gaining useful stability in weight bearing Arthrodesis of the hip joint is most readily accomplished by the use of an iliac graft (Figs 226 and 227) (For other technics in hip arthrodesis see Chapter 15)

Muscle transference Operations for Unstable Hip A number of substitution operations have been devised for this condition Lange Kreuscher, and others have utilized the erector spinae This is attached to all the vertebrae has a fairly limited excursion, and therefore seems far from ideal for the use to which it has been diverted The procedure which Ober and Hey Groves recommend is a modification utilizing the tensor fasciae femoris in addition This seems more logical though its field of usefulness must be limited to a few very carefully selected cases

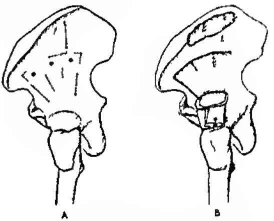


Fig 223 Shelf operation a modification of technic described by Lowman Three leaves of bone are cut with a chisel from the side of the ilium with drill holes and turned over in such a way that they overlap and are sutured to the capsule of the joint reinforced at their base by bone chips from the ilium

Tendon Transference of Erector Spinae and Tensor Fasciae Latae (Lange Ober Hey Groves *etc*) (Fig 228) A longitudinal incision is made from the first lumbar vertebra to the posterior superior iliac spine approximately *one inch lateral to* the spinous processes The lower five or six inches of the erector spinae muscle is mobilized by stripping it in the cleavage plane about one half inch lateral to the spinous processes The dissection then frees the tendinous insertion from the sacrum and from the posterior crest of the ilium The

FIG 224

FIG 225 A, B

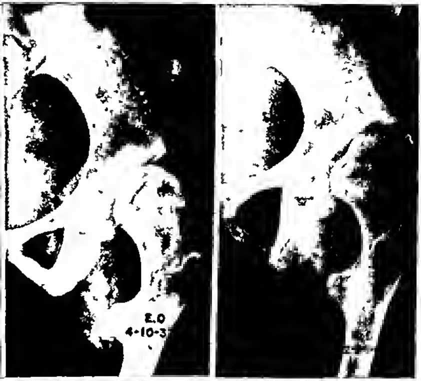


FIG 225 C

FIG 224 Photograph of girl standing with a stable left hip who had a shelf operation 3½ years previously for a subluxated left hip

FIG 225 Roentgenograms (A) Shows a subluxation of left hip joint (B and C) Show an effective shelf 3½ years later in anteroposterior and lateral views

muscle is separated along the lateral intermuscular septum down to the transverse processes and upward to the perforating dorsal nerves Great care should be exercised not to interfere with the nerve supply of the muscle

A second incision is made over the lateral side of the thigh from the top of the great trochanter to about one inch above the level of the patella A strip of fascia lata is dissected free up to and including the tensor fasciae latae Two inches below the base of the trochanter a tunnel is drilled through the femur from before backward The free end of the fascia lata is threaded through this tunnel from before backward The strip is pulled taut and sutured at the entrance and exit, and the free end is then drawn beneath the gluteal fascia to emerge at the lower end of the first incision where it is sutured to the free end of the erector spinae muscle under moderate tension After suture of the wounds a plaster of paris spica is applied and worn for three weeks At the end of this time the plaster spica is bivalved and exercises are commenced to increase the power in the transferred muscle

Other procedures for gluteal muscle weakness or paralysis have been described by Legg and by Wagner and Rizzo [The Legg procedure transfers the tensor fasciae femoris attachment from the front of the iliac crest to its middle third for gluteus medius paralysis Dickson transfers it to the posterior portion of the crest for gluteus maximus paralysis Wagner and Rizzo transfer the anterior thigh muscle origins posteriorly for the same effect —Ed]

Fig 226

Fig 227

Fig 226 (*Left*) A rather indistinct photograph (from a moving picture film) showing an extreme gluteal limp and instability of left hip joint (*Right*) Same patient five years later after arthrodesis of left hip Note that patient is practically able to balance herself bearing weight on left leg only She is wearing a slipper on right foot because of a recent minor operation on a toe

Fig 227 Roentgenograms of same patient showing (*left*) subluxated left hip and (*right*) arthrodesis of hip joint five years after operation

Knee Joint

The quadriceps femoris muscle is most apt to be involved with resulting flexion deformity if the hamstring muscles are active Hyperextension deformity or genu recurvatum occurs when the situation is reversed

Flexion Deformity This deformity is due to overpull of the hamstrings in the presence of weakness or paralysis of the quadriceps muscle The posterior capsule of the knee joint in time becomes thickened

and shortened and acts as a check to full extension. A great many of these contractures can be corrected by application of a circular plaster-of-paris splint which is hinged at the knee. The hinges should be placed anterior to the center of the knee joint to prevent posterior subluxation. The

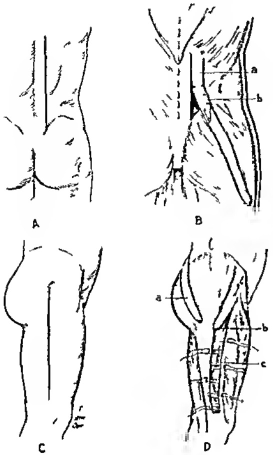


FIG 228 Transference of erector spinae and tensor fasciae latae to overcome instability and gluteal limp (A) A skin incision extending from region of first lumbar vertebra to posterior superior iliac spine approximately one inch lateral to spinous processes exposing deep fascia and muscles (B) (a) Outer half of erector spinae muscle group split off and dissected free from its attachment (b) method of suturing fascia lata to inferior surface of freed erector spinae muscle mass (C) Skin incision on lateral aspect of thigh from tip of trochanter to one inch above patella exposing fascia lata and tensor fasciae latae (D) Long flap of ten or fasciae latae 1¼ inches wide dissected free from thigh up to and including muscle fibers of tensor fasciae latae (a) Flap of fascia extending up to spinal muscles (b) hole drilled through femur at level of insertion of gluteus maximus tendon, (c) cut edges of fascia approximated with sutures

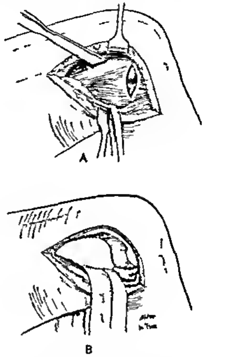


FIG 229 Capsulotomy at knee joint (A) Posterior capsulotomy of knee joint from lateral side Gastrocnemius origin and joint capsule are stripped subperiosteally from back of femur (B) Through a second medial incision subperiosteal stripping of posterior capsule is completed When posterior structures of capsule are completely freed, knee can be put in full extension

knee is gradually extended by a turnbuckle. Should the flexion deformity be very severe or resist the means described above, surgery must be resorted to. [Even when the hinges are properly placed, the use of excessive force in attempting to correct the severe and resistant flexion deformities may produce posterior subluxation of the tibia on the femur. X ray check against this should

be made during turnbuckle extension in severe cases —Ed]

The operation of posterior capsulotomy of the knee joint suggested by Wilson has been extremely satisfactory

Posterior Capsulotomy (Wilson) (Fig 229) Over the lateral side of the knee an incision is made from well above the condyle to the head of the fibula approximately then made from above the medial condyle to below the joint line The posterior medial compartment of the capsule is opened The same subperiosteal dissection is carried up the posterior surface of the femur With the knee flexed and the posterior soft tissues retracted the tight capsule at the intercondylar space is opened subperiosteally and divided The peroneal nerve should be

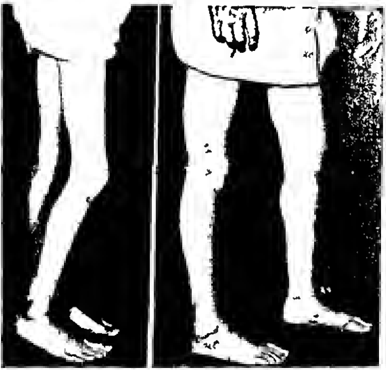


Fig 230 (*Left*) Photograph of patient with a right knee flexion deformity of 35° before operation (*Right*) Complete correction of flexion deformity following operative procedure

five inches in length The iliotibial band i divided transversely two inches proximal to the knee joint The biceps tendon is isolated for a distance of several inches above its insertion The peroneal nerve is visualized and retracted The biceps tendon is lengthened The capsule is opened at the posterior compartment and with a periosteal elevator it is subperiosteally stripped upward from the posterior surface of the femur several inches above the joint margin The outer head of the gastrocnemius is separated from the lateral condyle A median incision is protected and freed if it is tight on full extension After the wounds are sutured a circular plaster of paris splint is applied with the knee fully extended Careful attention must be paid to the circulation of the extremity After two weeks the splint may be bivalved and physical therapy started After another three to four weeks a ringlock brace is applied and walking allowed with the knee fully extended The brace should be worn for several months to prevent possible recurrence of the deformity

Genu Recurvatum or Back Knee This

deformity, due to complete paralysis or marked weakness of the hamstring muscles, is much less frequently encountered than is flexion deformity In a few instances it is a severe disability, and ingenious operative procedures have been devised to remedy the situation In most instances the disability of genu recurvatum may be corrected by operative procedures on the soft tissues The operation devised by Bruce Gill is aimed to create a new check ligament behind the knee joint

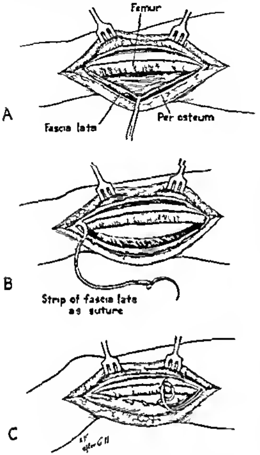


FIG 231 Operation designed to form a posterior check ligament at knee joint to prevent recurvatum (A) Incision through skin fascia lata, and periosteum and detachment of posterior third of periosteum from femur (B) Periosteum completely freed from femur and suture fashioned from an attached strip of fascia lata (C) Formation of new posterior check ligament of knee by suturing periosteum and fascia lata together

OPERATION FOR GENU RECURVATUM (BRUCE GILL) (Fig 231) A lateral incision is made from the midthigh to the head of the fibula and a similar medial incision is made The fascia lata is divided and the femur is exposed laterally and medially The periosteum is divided medially and laterally in such a manner as to leave a posterior strip which is roughly one third of its entire circumference This is stripped from the femur from above downward to the knee joint where it blends with the posterior and lateral ligaments of that joint The lateral ligaments are divided longitudinally The periosteal flap and the lateral ligaments are separated from the condyle of the femur and upper extremity of the tibia for a distance of approximately one half inch distal to the knee joint by an osteotome The posterior ligament of the knee joint is detached with the periosteum. A long strip of fascia is removed with its distal end attached This is used as a suture to approximate the free edges of the periosteum and fascia lata behind the femur while the knee is flexed The farther distally the suture is carried the more the check ligament is shortened and the less extension is possible After the wounds are closed, a plaster of paris splint is applied with the knee slightly flexed For a period of three months the knee must be protected against hyperextension (Fig 232)

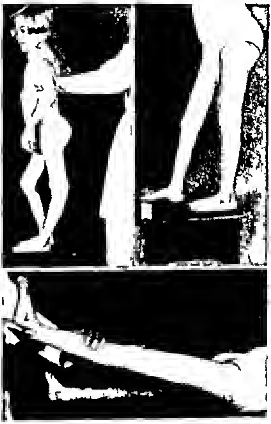
OPERATION ON BONY STRUCTURES TO PREVENT GENU RECURVATUM In certain instances where this recurvatum deformity cannot be controlled by means of a soft tissue operation, it may be necessary to resort to operation on the bones themselves Campbell and Mayer have proposed very interesting surgical procedures, each of which consists in making an "olecranon process" on the anterior superior articular surface of the tibia to impinge on the femur to prevent hyperextension Campbell uses the patella stripped of cartilage, and Mayer

a bone graft, to implant into a cleft driven into the upper surface of the tibia These procedures are both effective, but the indication for them will not be frequent

Paralysis of Quadriceps Femoris This frequently means an unstable knee joint which will usually require a ringlock brace to allow the patient to bear weight It is however, not infrequent to see a knee joint stabilized despite loss of power in the quadriceps muscle when the calf muscles and flexors at the hip joint are active Such a knee joint is locked in a little hyper extension each time the patient takes a step In an attempt to stabilize the knee joint and to allow active extension the paralyzed quadriceps is at times replaced by the active hamstring muscles This, of course, is not possible unless there are one or more active flexors of the knee joint It is usually not recommended unless the gastrocnemius muscle is active Under these circumstances it may quite often be an unnecessary procedure viewed from the standpoint of a stabilization of the knee joint In the presence of paralysis of the extensor muscles of the hip the operation will usually fail Should the occasion arise where it seems advisable to do a tendon transference at the knee to restore extensor power, any flexion deformity, if present, must be corrected either by supracondylar osteotomy or posterior capsulotomy Various muscles have been suggested and tried for transference to the patella The tensor fascia femoris and sartorius which would seem to be satisfactory from an anatomic standpoint, are inadequate, and the division of the tensor fascia femoris upsets the stability of the knee joint The semitendinosus and semimembranosus have not proved satisfactory, and it is pretty well agreed that the biceps femoris lends itself best to the operation, though the semitendinosus is at times used alone or in conjunction with the biceps

Transference of Biceps Femoris or Semitendinosus into Patella The best description of this operation is that of Crego and Fischer (Fig 233) An incision is made over the lateral side of the thigh from mid thigh to a point two to three inches distal

A B



C

Fig 232 (A) Photograph of patient aged seven with marked genu recurvatum of left knee (B and C) Same patient five years after operation No recurvatum on standing When patient lies down and pressure is applied to the leg and foot, there is no tendency to assume recurvatum deformity

to the fibular head The biceps insertion is divided with a small segment of bone or cartilage attached or an attached strip of fascia an inch or two distal to its insertion The tendon is retracted and the peroneal nerve should be visualized and carefully protected In order to free the biceps to

the midthigh it will be necessary to divide some of the muscle fibers of the short head which arise from the linea aspera to a point two inches above the lateral condyle The freed tendon is then passed obliquely through a subcutaneous tunnel into a second incision This second incision is made detaching it from its origin on the tibia beneath the sartorius This muscle, which has a long rounded free tendon, is also passed through a subcutaneous canal to a second incision and it in turn is sutured to the patella in a similar fashion, and the two transferred tendons are in turn sutured to

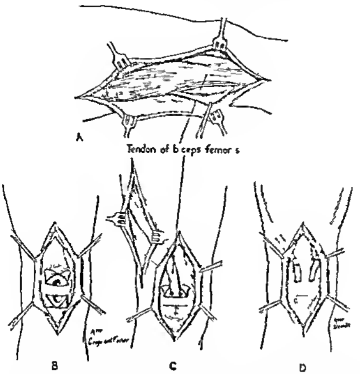


FIG 233 Transplantation of biceps femoris (and/or semitendinosus) (A) Exposure of biceps femoris muscle and tendon (B) Preparation of anterior surface of patella for reception of tendon or tendons into a vertical groove in patella, with drill holes for retention sutures (C) Tendon in place sutured to patella (D) An alternate method of suturing biceps or semitendinosus or both to patella suggested by Steindler

over the anterior medial aspect of the knee to expose the quadriceps tendon, patella, and ligamentum patellae The transferred tendon is then sutured subperiosteally into a groove in the patella using drill holes to anchor the sutures, or the tendon may be passed through a tunnel in the patella and sutured to itself If the semitendinosus tendon is used it must be secured through a medial incision of about the same length by each other After closure of the wounds the knee must be kept in complete extension with a circular plaster-of paris splint for from four to six weeks At the end of three weeks the plaster splint may be bivalved and active and passive motion allowed daily Weight bearing should be commenced at 8 to 10 weeks, using a ringlock brace to maintain extension for approximately two additional months It is, of course, neces

sary to re educate the transferred muscles from flexion to extension Complete extension *of the knee against gravity should* not be expected, but the increased power in the quadriceps is of value [Steindler's suggested alternative procedure is also shown in Fig 233]

The Completely Unstable Knee For the knee that is completely unstable and requires a ringlock brace to allow the patient to walk, in certain instances an arthrodesis offers the patient a chance to get rid assessing the value of a knee fusion in a patient with anterior poliomyelitis A per*manently stiff knee* has obvious disadvantages It gets in the way and is rather apt to be broken if there is a bad fall, but the mere freedom from a brace usually outweighs these objections in the patient's mind Braces, too, are awkward and they break, and the patient is at the mercy of the bracemaker The procedure of arthrodesis of the knee is most efficacious in those patients with paralysis limited *to one leg*

A B C

FIG 234

FIG 235

FIG 234 (A) Photograph of patient with extensive paralysis of both lower extremities with a flail left knee She was extremely helpless and dependent on braces (B and C) 10 years after arthrodesis *of left knee joint* which has made possible stable weight bearing and freedom from braces Feet are also stabilized

FIG 235 Roentgenogram of left knee of the patient shown in Fig 234 showing solid *arthrodesis of knee joint with trabeculation of bone extending across former joint line*

of his brace This operation preferably should be done after the age of 13 or 14, when the growth period is approaching its end *If the hamstring muscles are active, a* postoperative flexion or knock knee deformity is apt to develop through the ununited epiphyses if the operation is done at too early an age It is essential to allow the patient to make up his mind whether he prefers a stiff knee or a brace permanently There are very definite advantages and disadvantages to be considered in If both legs are badly paralyzed, an arthrodesis may be done on one knee while the opposite knee is stabilized by a brace There have been many technics advised for fusion of the knee joint, but for simplicity and ease, that of Hibbs stands up under the test of years

Arthrodesis of Knee (Hibbs) (Figs *234 and 235) A transversely curved incision* is made below the patella and deepened to the joint The cartilage is removed from the articular surface of the femur and

tibia The patella is entirely freed from its attachment and the articular cartilage is removed A groove is made in the intercondylar area of the tibia and the femur and into this the patella is mortised The periosteum of the patella is sutured across the front of the erased knee joint as the capsule is closed After closure of the wound a plaster of paris spica bandage is applied for several weeks followed by a long leg circular plaster of paris bandage which is worn until the fusion is solid This varies from four to eight months Weight bearing is allowed from 2½ to three months after operation (For other technics of knee fusion see Chapters 14 and 15)

Torsion of Tibia and Femur Torsion of the tibia and femur is not infrequently encountered in patients with anterior poliomyelitis and it may be corrected by osteotomy of the bone involved Tibial osteotomy should be performed at the upper extremity where healing takes place readily Femoral osteotomy for torsion is preferably performed in the supracondylar region after the proximal femoral fragment has been fixed by a steel pin through the shaft of the bone just below the trochanter In either case the distal fragments should be rotated medially or laterally as the occasion demands The extremity is immobilized in a circular plaster-of paris splint until the fracture is healed In the femoral osteotomy a plaster of paris spica will be required

Foot and Ankle

Since weight bearing begins with the foot, and because involvement of muscles controlling the foot and ankle is so frequently encountered as an aftermath of anterior poliomyelitis, there are numerous operations that have been devised to stabilize or improve the function of the paralyzed foot The ankle joint is a hinge joint with motion in two directions only, while the tarsal joints owing to their multiplicity, allow motion in all possible directions It is therefore possible for a patient with poliomyelitis to have a large variety of deformities of the foot such as *equinus*, due to paralysis of the anterior tibial group, *calcaneus*, due to paralysis of the triceps surae muscle, *valgus*, due to anterior and posterior tibial weakness or paralysis, *varus*, due to peroneal muscle weakness or paralysis, and *cavus*, due to paralysis or weakness of the intrinsic muscles of the feet These basic deformities are often present in combination, such as equinovarus or valgus, calcaneovalgus or equinocavovarus etc There is, finally, the foot which is totally lacking in muscle power, called the flail foot

The procedures devised to stabilize the feet are many, and the vast majority are directed to the bony structure of the foot in an attempt to provide a stable weight bearing mechanism in a favorable position Tendon transference has its place, but it is usually an adjunct to the stabilization operation, and only rarely will the transference of tendons serve by itself to produce a mechanism that will stand up under the stress of weight bearing

Clawfeet This is a deformity in which the toes are hyperextended at the metatarsophalangeal joints and flexed at the interphalangeal joints Painful calluses form beneath the metatarsal heads and corns on the involved toes The deformity varies from mildly hyperextended toes to a real cavus deformity of the foot with an enormously exaggerated arch with the forefoot gradually approximating the rearfoot If the deformity is mild, the simple removal of the deforming factors, the long toe extensor muscles will suffice The operation devised by Hibbs of transferring the long toe extensors to the cuneiform bones together with a plantar fasciotomy will correct the deformity and prevent its recurrence Since the short extensor to the great toe does not affect the interphalangeal joint it is invariably necessary to arthrodese this interphalangeal joint in the extended position Should the cavus deformity be severe in addition to the tendon transference it

will be necessary to do a wedge shaped section through the tarsus to correct the deformity

TRANSFERENCE OF EXTENSOR LONGUS DIGITORUM AND LONGUS HALLUCIS INTO CUNEIFORM BONES (HIBBS) (Fig 236) *Through a median longitudinal incision on* the dorsum of the foot, the extensor hallucis

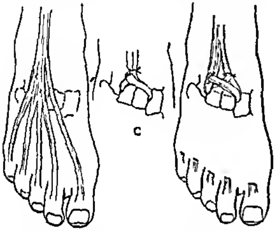


FIG 236 Transference of tendons of extensor digitorum longus and extensor hallucis longus to cuneiform bones for clawfoot A slight modification of technic originally described by Hibbs (A) General arrangement of extensor tendons to toes (B) *Tendons are divided as far* distally as possible A drill hole is made through the two lateral cuneiform bones and through this the extensor digitorum tendons are passed from lateral to medial side and the tendon of the extensor hallucis longus is passed from medial to lateral side and they are sutured to themselves and (C) to each other

longus and extensor digitorum longus tendons are isolated and divided as far distally as possible A tunnel is made through the middle and lateral cuneiform bones with a drill and the long toe extensor tendons are passed through this from lateral to medial side and the extensor hallucis longus from the medial to lateral side, and the tendons are then sutured to themselves and to each other A second incision is made at the medial *side of* the great toe at the inter phalangeal joint With a small osteotome the articular surface is removed and the toe is placed in full extension If necessary a small *incision is made* on the inner side of the heel and a subcutaneous division of the plantar fascia is done [Many men pre*fer to do a Steindler stripping rather than a* subcutaneous division of the plantar fascia It transfers the posterior attachment of the *fascia forward* without fear of further contracture of the fascia from operative scar

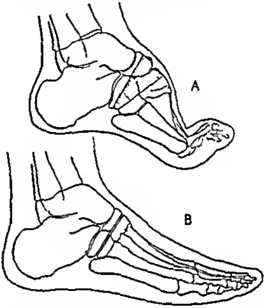


FIG 237 Diagrammatic representation of cavus foot showing (A) wedge of bone to be removed with base of wedge at dorsum of foot and apex at a point on plantar surface of foot *well below skeletal elements* (B) Removal of wedge with *correction* of cavus deformity

ring The incision is made over the inner side, extending from the posterior process forward to 1½ inches in front of the inner tubercle of the anterior process on a level with the deep surface of os calcis The plantar fascia is dissected free from its fatty and skin covering for its entire width *A transverse incision is then made through* the whole width of the blending of fascia with periosteum of os calcis The underlying muscles are stripped bluntly from the

peroneus longus, that an attempt is always made to use an existing tendon sheath If however the tendon will not glide freely because it is too crowded by already existing tendons, provided the tendon is passed beneath the annular ligament at the ankle the rest of its course may be directed subcutaneously

GROUP IV TRICEPS SURAE OR GASTROCNEMIUS AND SOLEUS MUSCLE INSUFFICIENCY The dynamic calcaneus foot is a very poor weight bearing mechanism seen with or without various combinations of lateral imbalance (1) In early cases without skeletal distortion and with weakness or paralysis of the triceps surae alone, a posterior transference of the tibialis anterior through the tendo achillis to the os calcis alone will suffice (2) In early cases with complicating lateral imbalance transference of the active invertors or evertors as the case may be, through the tendo achillis to the os calcis should be done (3) In late cases with skeletal distortion with lateral

The peroneus longus and tibialis posterior are withdrawn into this incision and passed through the sheath of the tendo achillis crossed behind the tendon, and each passed through the drill hole, the peroneal tendon passing from medial to lateral side and the posterior tibial tendon in the opposite direction The tendon ends are sutured to the os calcis and to the tendo achillis Peabody states that the tibialis posterior and peroneal muscle are short range stabilizing muscles and that their transference into the os calcis may prevent calcaneus but they will not develop sufficient power to permit a tiptoe gait He therefore prefers to transfer the tendon of the tibialis anterior muscle through a trap door in the interosseus membrane in the middle third of its extent along the course of the soleus muscle to the region of the tendo achillis where the anterior tibial tendon is inserted into the sheath of the tendo achillis through a split in the substance of the tendon and anchored in a drill hole in the os calcis

will be necessary to do a wedge shaped section through the tarsus to correct the deformity

Transference of Extensor Longus Digitorum and Longus Hallucis into Cuneiform Bones (Hibbs) (Fig 236) Through a median longitudinal incision on the dorsum of the foot, the extensor hallucis longus and extensor digitorum longus tendons are isolated and divided as far distally as possible A tunnel is made through the middle and lateral cuneiform bones with a drill and the long toe extensor tendons are passed through this from lateral to medial side and the extensor hallucis longus from the medial to lateral side, and the tendons are then sutured to themselves and to each other A second incision is made at the medial side of the great toe at the interphalangeal joint With a small osteotome the articular surface is removed and the toe is placed in full extension If necessary, a small incision is made on the inner side of the heel and a subcutaneous division of the plantar fascia is done [Many men prefer to do a Steindler stripping rather than a subcutaneous division of the plantar fascia It transfers the posterior attachment of the fascia forward without fear of further contracture of the fascia from operative scarring The incision is made over the inner side, extending from the posterior process forward to 1½ inches in front of the inner tubercle of the anterior process on a level with the deep surface of os calcis The plantar fascia is dissected free from its fatty and skin covering for its entire width A transverse incision is then made through the whole width of the blending of fascia with periosteum of os calcis The underlying muscles are stripped bluntly from the

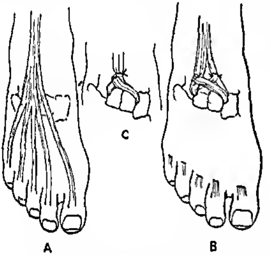


Fig 236 Transference of tendons of extensor digitorum longus and extensor hallucis longus to cuneiform bones for clawfoot A slight modification of technic originally described by Hibbs (A) General arrangement of extensor tendons to toes (B) Tendons are divided as far distally as possible A drill hole is made through the two lateral cuneiform bones and through this the extensor digitorum tendons are passed from lateral to medial side and the tendon of the extensor hallucis longus is passed from medial to lateral side and they are sutured to themselves and (C) to each other

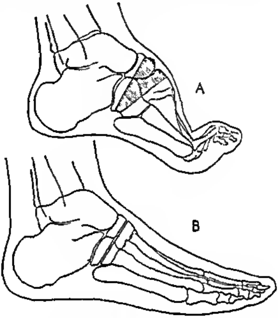


Fig 237 Diagrammatic representation of cavus foot showing (A) wedge of bone to be removed with base of wedge at dorsum of foot and apex at a point on plantar surface of foot *well below skeletal elements* (B) Removal of wedge with correction of cavus deformity

os calcis forward to the calcaneocuboid junction, together with the long plantar ligament running between the os calcis and the cuboid One must keep close to the ward, where they reattach in the corrected position of the foot —Ed]

In the presence of marked bony cavus deformity of the foot (Figs 237, 238, and

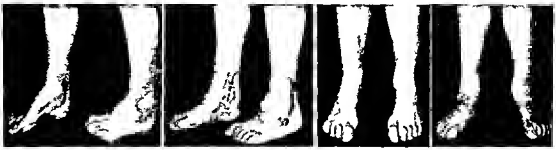


Fig 238 (*Left*) Photograph of patient with marked bilateral cavus deformity and clawfeet A five-year old boy with a definite history of anterior poliomyelitis during infancy (*Second third and fourth illustrations*) Photographs after tarsal section and transference of the long extensor tendon to cuneiform bones There has been a marked correction of deformity Patient was greatly improved from standpoints of comfort and stability

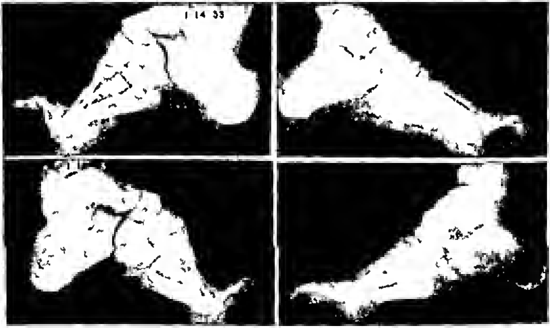


Fig 239 Lateral roentgenograms of cavus feet shown in Fig 238 before and after tarsal section and transference of long toe extensors Note that after operation, architecture of feet is relatively normal

bone at all times to avoid damage to the plantar vessels and nerves With the correction of the deformity following this procedure the attachments of the plantar fascia the underlying intrinsic muscles and the long plantar ligament are shifted for 239) a wedged osteotomy of the naviculocuneiform joint and through the cuboid bone is done This should be shaped so that the apex of the wedge is below the bones of the foot After closure of the wound a plaster of paris boot is applied with the

foot in the corrected position This boot is worn for a period of six weeks only if the tendon transference alone is done If a bony wedge has been excised from the tarsus, the boot should be worn from 10 to 12 weeks though weight bearing in plaster may be allowed after six weeks

OTHER TENDON TRANSFERENCE IN FOOT As a procedure per se, the transference of tendons of the foot has received but little recognition compared with the various stabilizing operations Mayer has written extensively from a technical standpoint and Peabody has presented interesting results in a large series of cases Peabody's classification of the various types of paralyses of the muscles affecting the foot and the indications for tendon transference are so clearly expressed that it seems advisable to include them in this presentation The technical details of tendon transference in the foot require a fundamental knowledge of the anatomy and muscular kinetics of the foot and some few details of the proper handling of the tendons which are to be rerouted Pre existing tendon sheaths should be utilized as far as possible or some gliding mechanism should be provided Tendon is attached more firmly and securely if it can be passed through a tunnel of bone Silk is, in all probability, the best suture material

GROUP I LIMITED EXTENSOR INVERTER INSUFFICIENCY, largely limited to weakness or paralysis of the tibialis anterior This is a *foot with inadequate dorsiflexion retracted* toes, and cavus deformity occurring as the effort is made to dorsiflex *the foot* On weight bearing these feet go into valgus or at times cavus In this type of foot, transference of the extensor hallucis longus into the base of the first metatarsal is sufficient except in cases where there is marked valgus, either relaxed or fixed, and in this type of foot an arthrodesis of the talonavicular joint is done in addition to the tendon transference In all instances the contracture of the Achilles tendon has to be overcome with either gradual stretching or surgical lengthening

Transference of Extensor Hallucis Tendon (Fig 240) An incision approximately three inches in length is made over the course of the extensor hallucis longus tendon The sheath is incised and the tendon

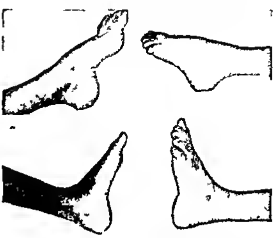


FIG 240 (*Left*) Photographs of a patient with limited extensor inverter insufficiency, with cavus deformity and retraction of toes on effort to dorsiflex foot (*Right*) Photographs of same patient s foot following transplant of extensor hallucis longus into base of first metatarsal and extensor longus digitorum into cuneiform bones with arthrodesis of great toe interphalangeal joint *It will be* noted that cavus deformity is practically *gone and patient now dorsiflexes foot* very well

is divided as far distal as possible, carefully *preserving the extensor brevis tendon* A tunnel is made in the base of the first metatarsal bone *and the tendon is passed* through this and sutured to itself The interphalangeal *joint of the great toe should be* arthrodesed in extension to prevent hammertoe In case there is marked valgus the talonavicular joint should be exposed by a medial longitudinal incision and the articular cartilage removed from the adjacent bone surfaces If good contact is secured a solid bony fusion should ensue A small bone graft from the lower tibia may be

added, and in small children it will be necessary This should be countersunk in a prepared trough in the talus and navicular bones After closure of the wounds, a circular plaster-of paris boot is applied to be worn for a period of six weeks if the tendon transference alone has been done, and up to 10 weeks if the arthrodesis has been added

241) In this type of foot it is at times necessary to supplement a tendon transference with a stabilization operation Through a small longitudinal incision at the calcaneocuboid joint the peroneus longus tendon is identified and divided as far distally as possible A second longitudinal incision 3 to 3½ inches long is made over the

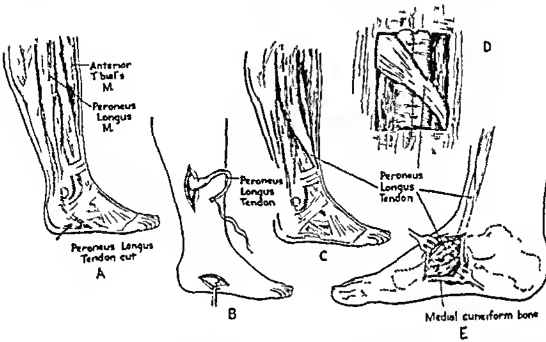


Fig 241 Transplant of peroneus longus tendon into middle cuneiform bone (A) Shows point at which peroneus longus tendon is cut on lateral side of foot (B) Peroneus longus tendon withdrawn into second incision (C) Peroneus longus rerouted toward dorsal surface of foot (D) Gliding mechanism devised by Mayer by suturing peroneal sheath to anterior tibial sheath (E) Insertion of peroneus longus tendon into a tunnel in dorsal surface of middle cuneiform bone

GROUP II GROSS EXTENSOR INVERTER INSUFFICIENCY *Type A* Weakness or paralysis of the long toe extensors and tibialis anterior with the posterior tibial muscle relatively unimpaired In this situation the peroneus longus is transferred to the dorsal aspect of the medial cuneiform bone In about one-half of these cases arthrodesis of the talonavicular joint is required where structural changes in bone or soft parts prevent satisfactory alignment

Transference of Peroneus Longus to Dorsal Surface of Medial Cuneiform Bone (Fig

course of the peroneal muscles in the lower third of the leg The peroneal sheath is incised and the longus tendon, which lies superficially, is withdrawn from the wound A gliding surface for the transferred tendon is formed by suturing the open peroneal sheath to the open anterior tibial sheath This is described by Mayer A third longitudinal incision is made over the medial cuneiform 2½ to 3 inches in length The sheath of the tibialis anterior tendon is opened, and a wire loop or tendon carrier is passed upward in the tendon sheath be

neath the anterior crural ligament to the second incision The tendon of the peroneus longus is then threaded through the sheath of the anterior tibial muscle and inserted in a tunnel at the dorsal surface of the medial cuneiform bone The tendon may be passed through a subcutaneous tunnel instead of utilizing the existing tendon sheath It has been shown by Peabody that if the transferred tendon is carried to the insertion of the tibialis anterior a valgus foot at times is converted into a varus foot A talonavicular or complete subtalar arthrodesis may be necessary to stabilize such feet After closing the wounds, a plaster of paris circular bandage is applied with the foot in the corrected position This is worn for six to eight weeks if tendon transference alone has been done, and for 10 to 12 weeks if bone stabilization has been added

Type B Severe Paralysis of Both Tibial Muscles and Long Toe Extensors In these feet both peronei are transferred to the dorsum of the foot, and in longstanding cases or in those with severe deformity, a subtalar arthrodesis is performed in addition

The technical procedure of transference of both peroneal muscles is similar to that described above except that the peroneus brevis is added and the two tendons are threaded through the tunnel on the dorsal surface of the middle and medial cuneiform bones These tendons are sutured to themselves and to each other after passing through the tunnel This foot will almost certainly require a subtalar arthrodesis

GROUP III EVERTOR INSUFFICIENCY—LOSS OF POWER OF THE PERONEI MUSCLES A transference of the extensor hallucis longus to the base of the fifth metatarsal bone is performed if the peronei show slight or moderate impairment or if there is slight weakness of the tibialis posterior When these muscles are more severely damaged, the tibialis anterior is transferred into the cuboid bone as well When there is complete peroneal muscle paralysis with a normal posterior tibial muscle, security against varus may be obtained only by tenotomy of the posterior tibial muscle Varus deformity or instability of long standing will always require stabilization by subtalar arthrodesis

Transference of Extensor Hallucis Longus Tendon to the Base of the Fifth Metatarsal Bone A median incision is made over the dorsal surface of the foot three to four inches in length The tendon of the extensor hallucis longus is isolated and divided as far distally as possible The interphalangeal joint of the great toe must be arthrodesed in extension in this case The tendon and as much of its sheath as possible is then redirected laterally across the dorsum of the foot to the base of the fifth metatarsal bone where through a second incision two inches long it is passed through a drill hole in the bone and sutured to itself

Transference of Anterior Tibial Muscle into the Cuboid Bone A longitudinal incision is made over the dorsal surface of the foot, in the midline, about three inches in length The tendon of the tibialis anterior is identified and divided at its insertion by retracting the skin medially As much of the sheath of the tendon as possible is preserved A second incision is made over the lateral side of the tarsus to expose the cuboid bone In this bone a tunnel is constructed from above downward and laterally with a drill and curet The tendon of the tibialis anterior is passed subcutaneously from the first incision to emerge at the second incision where it is threaded into the tunnel in the cuboid bone and sutured to itself with the foot at 90° to the long axis of the leg and neutral lateral position After closure of the wounds, a plaster-of paris bandage is applied to be worn six weeks if the tendon transference alone is done If a subtalar arthrodesis is done, a plaster-of paris bandage must be worn for from 10 to 12 weeks It should be noted in these various tendon transference operations, such as transference of the tibialis anterior and the

peroneus longus, that an attempt is always made to use an existing tendon sheath If however, the tendon will not glide freely because it is too crowded by already existing tendons, provided the tendon is passed beneath the annular ligament at the ankle the rest of its course may be directed subcutaneously

GROUP IV TRICEPS SURAE OR GASTROCNEMIUS AND SOLEUS MUSCLE INSUFFICIENCY The dynamic calcaneus foot is a very poor weight bearing mechanism seen with or without various combinations of lateral imbalance (1) In early cases without skeletal distortion and with weakness or paralysis of the triceps surae alone a posterior transference of the tibialis anterior through the tendo achillis to the os calcis alone will suffice (2) In early cases with complicating lateral imbalance transference of the active invertors or evertors, as the case may be, through the tendo achillis to the os calcis should be done (3) In late cases with skeletal distortion with lateral imbalance it is necessary to add a stabilization operation to the tendon transference procedure (4) In late cases with no lateral imbalance the stabilization operation with posterior transference of the peroneus longus and tibialis posterior is indicated The transference of the tibialis anterior whenever possible is the procedure of choice

In weakness or paralysis of the calf muscles it seems probable that no tendon transference alone will ever serve to stabilize or render the foot quite normal To replace the lost muscle power of the calf, Ober advocates transference of the peroneus longus and tibialis posterior to the os calcis as follows These tendons are divided as near their insertion as possible through small incisions on the medial and lateral side of the foot The lateral incision may be continued proximally exposing the Achilles tendon and os calcis A drill hole is then passed through the os calcis just in front of the insertion of the tendo achillis The peroneus longus and tibialis posterior are withdrawn into this incision and passed through the sheath of the tendo achillis, crossed behind the tendon and each passed through the drill hole, the peroneal tendon passing from medial to lateral side and the posterior tibial tendon in the opposite direction The tendon ends are sutured to the os calcis and to the tendo achillis Peabody states that the tibialis posterior and peroneal muscle are short range stabilizing muscles and that their transference into the os calcis may prevent calcaneus but they will not develop sufficient power to permit a tiptoe gait He therefore prefers to transfer the tendon of the tibialis anterior muscle through a trap door in the interosseus membrane in the middle third of its extent along the course of the soleus muscle to the region of the tendo achillis where the anterior tibial tendon is inserted into the sheath of the tendo achillis through a split in the substance of the tendon and anchored in a drill hole in the os calcis

STABILIZATION OF FOOT

The foot damaged as a result of anterior poliomyelitis may be stabilized with deformity corrected by means of various surgical procedures which are designed to eliminate lateral mobility This motion takes place chiefly if not entirely in the joints beneath and distal to the talus Davis, Hoke, Ryerson, Campbell Dunn, Whitman Brewster, and others have written extensively of various procedures which have been found useful in securing stability of the paralyzed foot The principles involved in these procedures are quite simple, but their application and indication require considerable experience

It is now pretty universally conceded that effective stabilization of the paralytic foot is secured only by arthrodesis of the talocalcaneal, talonavicular, and calcaneocuboid joints This procedure is called a subtalar or subastragalar arthrodesis and by some a triple arthrodesis The procedure cannot

be done satisfactorily on immature feet as the bones are too much in the cartilage stage and failure of fusion or growth disturbance may ensue No definite arbitrary age limit may be established, but the roentgenograms of the foot will tell quite readily whether the stage of ossification is such as to warrant attempt at surgical fusion An extremely important factor to be borne in mind is the continued unopposed pull of unparalyzed muscles upon these feet in which arthrodesis is to be done *These dynamic deforming factors must be neutralized by tendon transference to a neutral position or the deformity will recur*

Subtalar Arthrodesis (Fig 242) The operation of subtalar arthrodesis has many variations depending upon the deformity to be corrected, but basically the fundamental procedures are alike in all instances After a tourniquet has been applied to the upper thigh, the joints are exposed through a lateral incision, which may be curved or straight, extending from just in front of the lateral malleolus forward over the calcaneocuboid joint to the lateral surface of the foot The extensor digitorum brevis muscle is exposed and detached with a periosteal elevator from the os calcis and reflected forward The os calcis cuboid and navicular bones are exposed subperiosteally, carefully protecting the common extensor tendons in front and the peroneal tendons posteriorly The soft tissues in the interval between the talus and the os calcis are removed with a curette The next step is the excision of the articular surfaces At this point the deformity must be borne in mind and the procedure planned accordingly With an osteotome the head and neck of the talus is excised with

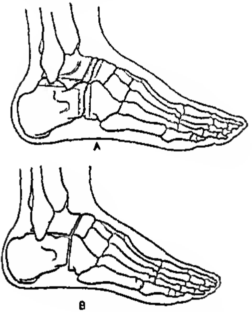


Fig 242

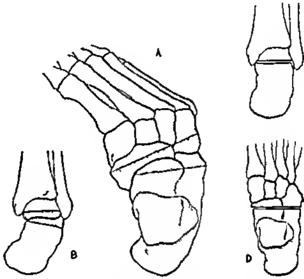
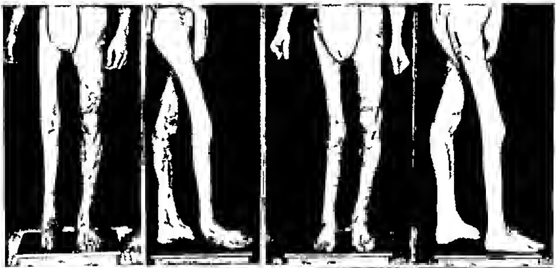


Fig 243

Fig 242 A diagrammatic representation of a subtalar or triple arthrodesis (A) Shaded area shows joints and adjacent bone removed from talus and navicular, talus and os calcis and os calcis and cuboid bones (B) Skeleton of foot after removal of articular surface with bones in contact

Fig 243 A diagrammatic representation of a foot with varus deformity It will be noted that the wedges of bone removed from talus and navicular os calcis and cuboid and talus and os calcis joints (A and B) have their bases directed to outer side and their apexes to inner side of foot in order to allow correction of varus deformity (C and D)



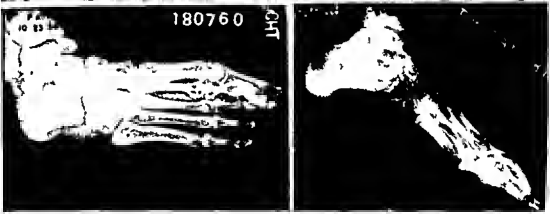


Fig 244 (*Top*) (A and B) Photographs of a 23 year old man with marked equinovarus deformity of the right foot following an anterior poliomyelitis at age three (C and D) Photographs taken five years after operative correction by subtalar arthrodesis with wedge osteotomies

Fig 245 (*Bottom*) Lateral roentgenograms of right foot of patient shown in Fig 244 (*Left*) Shows marked distortion due to varus deformity (*Right*) Shows correction of deformity in a stable weight bearing position after subtalar arthrodesis with wedge osteotomy

the adjacent articular surface of the navicular bone In a similar manner and with parallel cuts the articular surface of the calcaneocuboid joint is excised If the foot is in varus (Fig 243) bone removed from these two joints should constitute a wedge with its base directed laterally and its apex medially sufficient in size to bring the foot into neutral position (Figs 244 and 245) On the other hand if the foot is in valgus (Figs 246, 247, and 248) the wedge has its base to the medial side and its apex laterally If there is a cavus deformity (Fig 237) by itself or in addition to the others, the wedge will have to be planned in such a way that the base is directed to the dorsal aspect and its apex to the plantar aspect of the foot After completion of the procedure on the forefoot, the joint between the talus and os calcis is excised with an osteotome Here again wedges of bone removed depend on the deformity encountered If the foot is in varus (Fig 243) the wedge has its base to the lateral side and its apex medially and if it is in valgus the wedge has its base to the medial side and its apex laterally (Fig 246) If, however, the foot is of the calcaneus type (Fig 249) the wedge has its base posteriorly and its apex anteriorly In most instances, the ligaments should be loosened sufficiently so that the foot can be set backward beneath the long axis of the tibia to lengthen the posterior or short arm of the lever If the bony apposition is satisfactory, it is usually unnecessary to insert small bone chips The wound is sutured with one layer of interrupted silk with the foot in neutral position laterally, and in slight equinus A circular plaster of paris splint is applied from toes to the mid thigh with the knee flexed unless there is reason to guard against a flexion deformity at that joint The circular plaster should be split and bandaged The sutures are removed at two weeks after operation and a plaster boot is applied from toes to below the knee The patient is allowed to bear weight in this boot after six weeks have elapsed from time of operation This support is discarded at 10 to 12 weeks after operation and no further support should be necessary [For other technics of wedge stabilizations, see Chapter 3 —Ed]

Astragalectomy Excision of the talus or *astragalus* to stabilize paralytic feet especially of the calcaneovalgus type, has been advocated and practiced by Whitman It is said to be a more satisfactory procedure in children than in adults A slight shortening

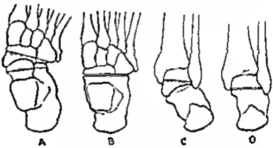


Fig 246 A diagrammatic representation of subtalar arthrodesis in a valgus foot Wedges removed from joints in this instance have their bases directed to medial side and their apices to lateral side (A and C) Show foot in valgus with shaded areas to be removed (B and D) show foot in corrected position after removal of wedges of bone and joint

of the leg ensues The fact that this procedure has relatively few adherents in all probability means that equally good or better results may be obtained by wedge arthrodesis of the subtalar joints

Bone block Procedures Following arthrodesis of the subtalar joint there may be persisting equinus or calcaneus deformity An attempt to remedy these has been made by various ankle block procedures An anterior block to prevent an extreme calcaneus has been devised by Putti and posterior blocks have been devised by Campbell, Gill, Wagner, and others These blocks tend to disappear if inserted before the patient is 12 or 13 years of age, and if they are markedly effective the mortise of the ankle joint is apt to be sprung The posterior ankle block if successful will prevent the rearfoot

Fig 247

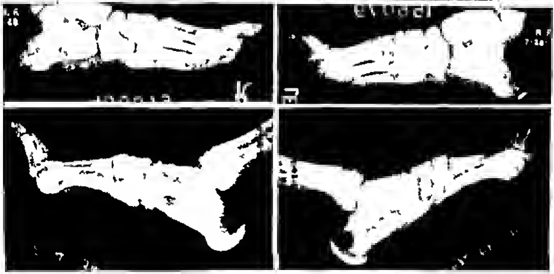


Fig 248

Fig 247 (*Left*) Photograph of valgus feet due to anterior poliomyelitis in a boy aged eight (*Right*) 6½ years after stabilization operation by subtalar arthrodeses with wedge osteotomies

Fig 248 Lateral roentgenograms of patient shown in Fig 247 at time of operation and 6½ years after operation Attention should be directed in the postoperative roentgenograms to the blending of the os calcis, cuboid, navicular, and talus into one bone, with trabeculation extending across former joint lines

from dropping but it exerts very little control over the forefoot (Fig 250) A more effective means of controlling either the calcaneus or the flail foot is a fusion at the ankle joint with the foot in a few degrees of equinus This is performed after the subtalar arthrodesis (Figs 251 and 252) [For technics of ankle joint fusions see Chapter 15 —Ed]

EQUALIZATION OF LENGTH OF LEGS

The failure of one lower extremity affected by anterior poliomyelitis to keep up its regular growth at times leads to a distressing difference in length of legs which may be a major handicap It should be recalled that there is no means of foretelling the amount of shortening to be anticipated in anterior poliomyelitis involving a lower extremity At times with almost complete paralysis there is no shortening and in other instances with but slight paralysis the affected leg lags behind in growth A difference in leg length of more than two inches is unusual though instances of as much as five inches difference have been recorded A one inch difference or less may usually be completely disregarded and a difference of 1 to 1½ inches or even more can be compensated by a raised heel on the shoe or an extension sole and heel

The indications for attempting equalization of the legs of a patient affected by anterior poliomyelitis should be carefully studied The discrepancy in length should be sufficient to make it a real disability Most of these patients with short legs due to anterior poliomyelitis have extensive paralysis affecting the muscles controlling the hip knee and foot and the great bulk of their disability is due to this muscle weakness which will not be affected by any equalization of the lower extremities

There are two avenues of approach to the problem of leg equalization

1 Lengthening of the short leg
2 Shortening of the long leg This may be accomplished by (a) growth arrest or (b) shortening of the tibia and fibula or femur

Lengthening of Short Leg

This is by far the most formidable of the three procedures designed to equalize the length of extremities and it is pretty well conceded that it should not be lightly undertaken On the face of it leg lengthening seems logical because it is an attempt to

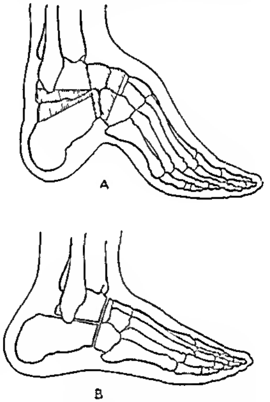


Fig 249 A diagrammatic representation of a calcaneocavus foot (A) Shows wedge of bone to be removed from midtarsal region with its base directed dorsally and its apex to plantar surface Wedge of bone to be removed at talo calcaneus joint proper has its apex directed anteriorly and its base posteriorly (B) Shows bony apposition obtained after wedges of bone and joint have been removed and it should be noted that os calcis has been set backward beneath talus in order to lengthen short arm of lever

Fig 250

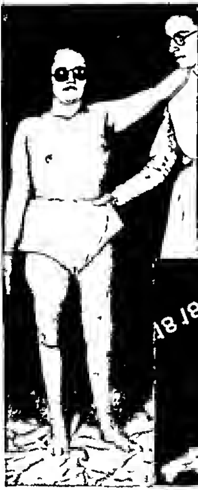


Fig 252 A

Fig 252 B

Fig 251

For legends see p 241

create a whole individual with well proportioned legs The sound leg is left undisturbed and, therefore can be relied upon should disaster occur It is doubtful if any surgeon who has done a reasonable number of these lengthening procedures has not narrowly missed disaster, if he has not actually encountered it Delayed union and infection are seen all too frequently in these sub par tissues which are further devital ized by the trauma of distraction In the hands of a few surgeons the procedure, with all its risks fully understood, may be done with reasonable chance of success, but its general use by the inexperienced is an invi tation to surgical disaster in the way of nonunion, necrosis of skin, osteomyelitis from wound infection etc The formidable nature of the operation should be fully understood and stressed Convalescence is extremely long at times up to one year or more Supplementary bone graft operations frequently have to be performed to hasten union The amount of suffering involved cannot be disregarded In fairness to the patient

The various procedures advocated for lengthening the lower extremity have been largely directed at the tibia and fibula be cause of their easier control during the process of distraction and the lessened chance of infection delayed union or non union all of which must be carefully guarded against

Putti Abbott, Crego Brockway, Compere Alcorn and Bosworth have described vari ous technics of leg lengthening I have observed a number of cases and done a few by the Bosworth method It is as simple as any and it is effective

Distraction of Tibia and Fibula (Bos worth) (Figs 253 254 255 and 256) The apparatus used consists of two side bars with a ratchet for distraction operated by keys pin guides and four pins The side bars are perforated at half inch interval to receive the pins which are locked by set screws to the bars (Fig 253) Kirschner wires and spreaders may be u ed with si le bars especially perforated for their use The operative procedure is as follows A tour niquet is used at the upper thigh

1 Lengthening of the tendo achillis by a double L incision

2 Insertion of pins The four pins are inserted into the tibial shaft two through the upper and two through the lower tibial *metaphysis* The pins of each pair are sepa rated from each other by one inch The skin in each instance is retracted as forcibly as possible toward the center of the leg before insertion of the pin to allow in part for *subsequent stretching* The pin guide is placed firmly against the inner side of the leg with the templet of the guide parallel to the sagittal plane of the tibia The guide will mark on the skin the site for the four pins These tibial pins are designated as A B C, and D from above downward Pin D is inserted with a hand drill through the pin guide, transfixing the tibial shaft The sec ond pin to be inserted is pin C The third pin to be inserted is pin A Then in placing the fourth pin B the pin guide should be *sprung forward* approximately a quarter inch by removal of the guide from pin A

Fig 250 Postoperative roentgenograms seven years after subtalar arthrodesis and posterior ankle-block operation Note that while ankle block holds rearfoot at approximately 100 to 105° os plantar flexion forefoot actually drops into approximately 130 to 140° of plantar flexion

Fig 251 Photograph of patient with flail left knee who was totally unable to stand before operation ankle and foot stabilized by right and left subtalar arthrodeses arthrodesis of left knee joint and arthrodesis of left ankle joint following subtalar arthrodesis

Fig 252 (A) Preoperative roentgenogram of left flail foot of patient shown in Fig 251 showing extreme equinus position (B) Postoperative roentgenogram showing subtalar arthrodesis and arthrodesis of ankle joint giving stable weight bearing in presence of com plete paralysis

This offset of pin B serves to keep the tibial fragments in contact and to prevent anterior bowing. A fifth pin is now inserted through the os calcis. Dressings are carefully placed on the skin at the sites of all emerging pins.

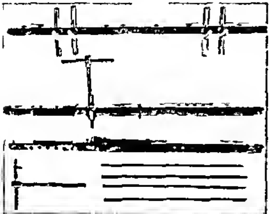


FIG 253 (*Top*) Photograph of Bosworth leg lengthening apparatus from above downward: pin guide with templets inserted and fixed with set screws. The two side bars with ratchets operated as shown by two keys. These bars are perforated at half inch intervals to receive the four Steinmann pins which are shown. (Courtesy, David M Bosworth.)

FIG 254 (*Bottom*) Bosworth apparatus consisting of two side arms attached by four pins to tibial shaft. Tongue and groove osteotomy of tibia and transverse osteotomy of fibula and pin through os calcis to support foot are also shown; suspension of apparatus to overhead frame by means of wires attached to pins is also shown. Attention is called to fact that the two keys are each inserted into the side arms and that the distraction is carried on by turning both of these keys simultaneously. (Courtesy, David M Bosworth.)

3 Osteotomy of tibia and fibula. Through an anterior medial incision, the tibial shaft is exposed subperiosteally at its central portion. With a motor saw the tibial cortex is cut longitudinally on its medial and lateral surface for a distance of approximately four inches. Distally these cuts in the bone are joined transversely and anteriorly with a fine osteotome dividing the tibial crest. Proximally the osteotomy is completed posteriorly with a Gigli saw. This leaves a tongue above and groove below. The fibula may then be divided through this incision exposing it subperiosteally by following the interosseus membrane, taking due care to protect the vessels and nerves. Usually no division of the fascia has been necessary.

4 The side arms are now placed over the pins and secured with the set screws. About a quarter inch of lengthening is at once secured with the keys to stabilize the extremity. The wounds are closed with a single layer of interrupted silk and dressings are applied. The apparatus is readily suspended with balanced overhead traction to a balkan frame with a sling of muslin or flannel placed beneath the calf. The foot is supported by the pin through the os calcis. Sutures are removed on the seventh day and the distraction is not commenced until another two or three days have elapsed (Fig 254).

5 The lengthening of the extremity is commenced when healing of the wound is definite. The keys in the side arms are turned one notch, or a tenth of an inch every other day, and the side arms are securely locked at the added length. In children this lengthening may proceed a little more rapidly.

6 Fixation of the extremity. When the desired increase in length has been obtained the pin through the os calcis is removed by cutting it with sterile rivet shears adjacent to the skin, painting the area with 7 per cent iodine and withdrawing it from the opposite side. [Another method of withdrawing pins

is to heat the projecting point end to a dull heat with an alcohol lamp, the skin being protected by a piece of cardboard slipped over the pin When the pin is pulled through from the opposite side the heated end sterilizes the tract as it goes through the tissues —Ed] A circular plaster-of-paris bandage is then applied from the toes to the midthigh, firmly incorporating the four tibial pins. After this sets, the side arms are removed by cutting the pins with rivet shears After a few days the patient may be allowed up with crutches

7. In most instances if the patient is over 12 years of age a bone graft of the upper tibial shaft should be done. This may be performed through a window in the circular plaster bandage The circular plaster splint with the pins incorporated is worn until union of the fragments is certain, an

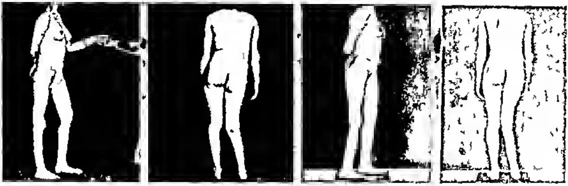


Fig. 255 Photograph of a girl aged 18 who contracted anterior poliomyelitis at age two At time of operation her right leg measured 28½ inches and her left leg 31½ inches in length (A and B) Show patient before operation She has a marked pelvic tilt, and, in order to stand on both feet, must flex her good leg (C and D) Show patient after two inches' length had been added by distraction of tibia and fibula Attention is called to fact that her posture is very greatly improved She still has some knock-knee and slight anterior bowing of lengthened tibia.

Fig 256. Roentgenograms taken during process of distraction of tibia and fibula on patient shown in Fig 255, immediately after operation, during course of lengthening, and end-result. It will be noted that this patient healed with some anterior bowing of her tibia owing to fact that she was probably not immobilized long enough in plaster-of-paris.

average time of three to five months The pins are then removed and another circular plaster splint is then applied and worn for an average of seven to nine months The entire procedure will require approximately one year By this method an average gain in length of shortened extremities of approximately two inches has been obtained with one instance where the increased length was 3½ inches (Figs 255 and 256)

The surgeon should have all the facts in mind before he embarks on a procedure of such magnitude and be quite certain that the end result will justify it

Leg Shortening

Leg shortening of any type deals with the sound leg and the objections are obvious—namely that any chance of such complications as infection or nonunion would indeed be a catastrophe It seems that the answer to this is equally obvious The surgeon is dealing with sound healthy tissues and the operative procedures are infinitely less damaging and insulting to these tissues than are those involved in lengthening an extremity Under these circumstances a surgeon whose technic is uncertain and not skillful enough to avoid the complication of nonunion and infection except as a remote and totally unforeseen chance should avoid these and perhaps all other operative procedures on bones or joints

Arrest of Growth of Bone This is frequently called epiphyseal arrest but it is actually the metaphysis which ceases to grow in length when there is an erasure of the epiphyseal cartilage White uses the term metaphyseal arrest while many others prefer to use epiphyseal arrest Erasure of the epiphyseal cartilage plate results in a fusion of the epiphysis and diaphysis and the term epiphyseo diaphyseal fusion is accurate and descriptive of the condition which is surgically produced Phemister and White have contributed considerable valuable data on this subject As a method of leg equalization it can of course, be applied only to the growing child For the successful application of this method to equalize the length of legs a large amount of detailed and intricate knowledge of growth in children is necessary A number of objections to the use of growth arrest have been vigorously stated The most important of these is that there is no absolute criterion for determining how much an individual child will grow It may also be said that there are as yet relatively few end results and that these are of short duration

The standards used in attempting to compute expected growth in an individual have been rather crude The comparative heights of the two parents may vary up to 14 inches and over Which parent the child will resemble at full stature it is quite impossible to predict To attempt to estimate expected bone growth on the basis of the average from prepared tables is a weak reed to lean upon when there is a known variation of over nine inches in boys and over seven inches in girls when growth is completed The long bones grow at different rates at various times during the growth period

It is generally agreed that the femur achieves approximately ¾ of its growth from the distal metaphysis and the tibia and fibula approximately 3/5 of their growth from the proximal metaphysis and that almost 70 per cent of the growth of the lower extremity takes place at the distal femoral and proximal tibial and fibular metaphyses Therefore any attempt to arrest growth in the lower extremity will usually be directed at these areas White has stated that ¼ to ⅜ of an inch shortening per year during growth will ensue following a destruction of the lower femoral epiphyseal cartilage plate and that if the upper tibial and fibular epiphyseal plates are similarly destroyed twice that amount of shortening may be expected

The most significant study of this subject of growth of the femur and tibia has been completed by Gill and Abbott They have removed the computation of bone growth

from the realm of guessing to what appears to be scientific accuracy In a recent presentation, as yet unpublished "A Practical Method for the Prediction of the Growth of the Femur and Tibia in the Individual Child," these authors have made, I believe a very significant contribution to the subject of growth arrest With their permission the method is presented in abstract form

Determination of Expected Growth of Normal Femur and Tibia

I Essential Data Required A AGE OF CHILD IN YEARS AND MONTHS

B SKELETAL MATURATION AGE, which may be determined by comparison of an anteroposterior x ray of the hand with the standards in Todd s Atlas for the hand (Todd T W Atlas of Skeletal Maturation (Hand), St Louis, C V Mosby Co)

The skeletal maturation age may also be determined from the knee but, unfortunately, Todd s standards for the knee are not printed in Atlas form For this reason it is simpler to determine the skeletal maturation age from the hand

C TOTAL HEIGHT This measurement is taken with the patient standing on the normal leg Blocks are placed under the short leg until the pelvis is level The buttocks shoulders and head should touch the wall

D LENGTHS OF FEMUR AND TIBIA This is to be determined from x rays of the femur and tibia taken at a distance of six feet, the tube to be centered in the approximate middle of each bone From these films the measurements are made as follows

FEMUR—straight line from tip of femoral head to medial lip of internal femoral condyle at joint line

TIBIA—straight line from medial lip of internal tibial condyle at joint line to tip of internal malleolus

E CALCULATION OF LENGTH OF NORMAL FEMUR AND TIBIA AS PERCENTAGE OF STATURE From the height and the lengths of the normal femur and tibia the present femoral and tibial percentages of stature are calculated as follows

Femoral per cent of stature = Length femur/stature × 100

Tibial per cent of stature = Length tibia/stature × 100

II Estimation of Length of Normal Femur and Tibia at Completed Growth

A ESTIMATION OF EXPECTED FINAL STATURE From the sex, present age, and height, the individual is placed in his or her percentile position in the Percentile Chart (Fig 257) If the skeletal maturation age is more than six months advanced or retarded the age charted should be the bone maturation age By following up the chart between the parallel percentile curves the expected final stature of that individual is obtained

B ESTIMATION OF NORMAL FEMORAL AND TIBIAL PERCENTAGES OF ADULT STATURE To the present percentages of the normal femur and tibia to stature as calculated above in I, E, are added the amounts either positive or negative as given in the adjoining subtable according to the sex and the corrected age This will give the estimated adult percentages of these bones to final stature

C CALCULATION OF EXPECTED FINAL LENGTH OF NORMAL FEMUR AND TIBIA This is calculated from the data obtained above in II, A and B, as follows

Final length normal femur = Expected final stature × adult femoral per cent of stature

Final length normal tibia = Expected final stature × adult tibial per cent of stature

III Expected Growth from Normal Femur and Tibia

Expected growth of normal femur = Expected final length of femur — present length of femur

Expected growth of normal tibia = Expected final length of femur — present length of tibia

IV Expected Growth from Individual Epiphyses of Normal Femur and Tibia

Growth from distal femur = Expected femoral growth × 70 per cent

Growth from proximal tibia = Expected tibial growth × 55 per cent

Growth from distal tibia = Expected tibial growth × 45 per cent

Determination of Expected Growth of Abnormal Femur and Tibia

This method will give only the expected growth of the normal femur and tibia This information will aid in determining the growth of the shorter leg if in each case a careful study is made of the mechanism of production of the inequality as it relates to the growth of the individual epiphyses of the involved limb There are three such mechanisms A brief discussion of the most common example of each follows

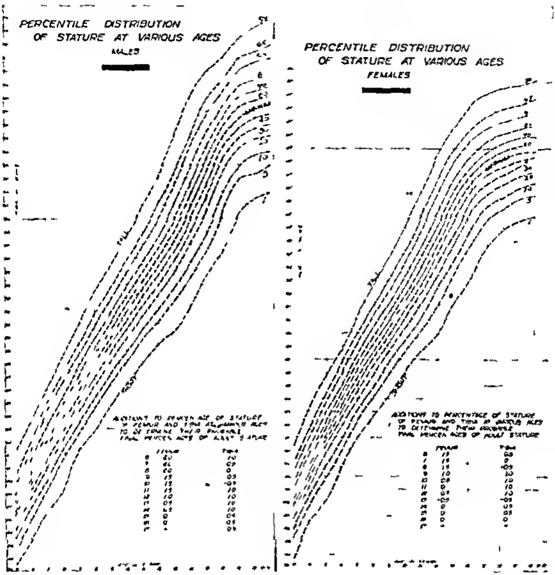


FIG 257 Percentile charts drawn by Doctor Gill from tables for percentile distribution of stature given by White House Conference on Growth and Development. Subtables in lower right corners of charts give additions to percentage of femur and tibia to stature at various ages necessary to determine final percentages of these bones to adult stature These subtables are constructed from a compilation of the work of Davenport, Schwerz, Meredith, and Boynton (*Left*) Percentile chart for males (*Right*) Percentile chart for females (Courtesy, Dr Gerald Gill and LeRoy C. Abbott)

1 **Disturbances Confined to Specific Epiphyseal Plates** This mechanism most commonly follows trauma which has caused premature closure of a specific epiphysis As the other epiphyses of that limb usually grow at the normal rate the loss of growth is that amount which would have been contributed by the center damaged For this reason, the calculations may be made entirely on the basis of the expected growth of the normal leg

2 **Disturbances Affecting Rate of Growth of All Epiphyses of Limb** [This applies to the shortening of an extremity due to anterior poliomyelitis —Ed] This mechanism most commonly follows poliomyelitis but may be caused by any long standing disabling condition of the extremity In this group the epiphyseal plates *are intact* but *growing at a* decreased rate as compared with the normal side In these cases great difficulty is often encountered in assessing the comparative rates of growth of the normal and abnormal limbs

In some instances this information may be obtained by placing a small vitallium marker in the shaft of the femur and tibia of the normal and the short leg We have devised a simple method by which these may be introduced subcutaneously under local anesthesia Teleroentgenograms are taken immediately after their implantation and then at six month intervals In this manner we can measure the growth from each epiphysis of both legs and can determine the comparative rates of growth From this information the growth of the shorter leg can be calculated quite accurately

Of course some children are seen so near the end of the growth period that no time is allowed for such studies In these instances epiphyseal arrest may be safely performed on the basis of the normal rate of growth Equalization will then result only to the extent to which the corresponding epiphyses of the short leg grow

Fortunately, in many of these patients seen at the age of 11 or 12 in whom the mechanism has been acting since early childhood or infancy only from two to three inches of shortening is present Simple analysis of the difference in the length of the bones when compared with the probable growth since the onset of the disease as may be determined by calculating backward with our method will show that the actual growth rate of the abnormal leg is so close to that of the normal leg about 85 per cent that for all practical purposes *the expected growth may be calculated* on the basis of the growth of the normal leg

3 **Mechanical Loss in Length** (may be associated with mechanisms 1 and 2) In the third group are placed those cases in which all or the greater part of the inequality is due to a mechanical cause such as loss of substance overriding dislocation or angulation If study shows that the loss in length has been purely mechanical then the rate of growth of the epiphyses is normal and the *epiphyseal arrest* may be carried out on the basis of the normal rate of growth In many cases there is also a loss of growth due to one of the foregoing mechanisms In such cases the rate of growth may be determined as above and epiphyseal arrest performed on the basis of this rate

The following example will serve to clarify the various steps in predicting the growth of the normal femur and tibia

Given a girl, age 9 years (I, A) — *Height* = 53 *inches* (I, C)

Bone maturation age 10 years (I B)

Length of femur = 14 8 inches — Length of tibia = 12 5 inches (I D)

Femoral per cent of stature $= \frac{14\ 8 \times 100}{53} = 28$ *per cent* *Tibial per cent of stature* $= \frac{12\ 5 \times 100}{53} = 23\ 5$ per cent (I, E)

The expected total stature = 64 inches (II, A)

$\left.\begin{array}{l}\text{Femoral per cent of adult stature} = 28 + 0\ 5 = 28\ 5 \text{ per cent}\\ \text{Tibial per cent of adult stature} = 23\ 5 + (-1\ 0) = 22\ 5 \text{ per cent}\end{array}\right\}$ (II B)

$\left.\begin{array}{l}\text{Final length femur} = 28\ 5 \text{ per cent} \times 64 = 18\ 2 \text{ inches}\\ \text{Final length tibia} = 22\ 5 \text{ per cent} \times 64 = 14\ 4 \text{ inches}\end{array}\right\}$ (II, C)

$\left.\begin{array}{l}\text{Expected growth femur} = 18\ 2 - 14\ 8 = 3\ 4 \text{ inches}\\ \text{Expected growth tibia} = 14\ 4 - 12\ 5 = 1\ 9 \text{ inches}\end{array}\right\}$ (III)

$\left.\begin{array}{l}\text{Growth distal femur} = 3\ 4 \times 70 \text{ per cent} = 2\ 4 \text{ inches}\\ \text{Growth proximal tibia} = 1\ 9 \times 55 \text{ per cent} = 1\ 05 \text{ inches}\\ \text{Growth distal tibia} = 1\ 9 \times 45 \text{ per cent} = 0\ 85 \text{ inches}\end{array}\right\}$ (IV)

Let us suppose that just before the age of eight years this child had suffered an injury which had caused premature closure of the distal epiphysis of one femur resulting in a shortening of one inch With no treatment the final shortening of the femur will be 1 + 2 4 inches or 3 4 inches Immediate fusion of the distal femoral epiphysis will prevent an increase in inequality but leave the one inch discrepancy To gain complete equality the upper tibial epiphysis could be blocked at this time The stature would then be 64 minus 3 4, or 60 6 inches at full growth

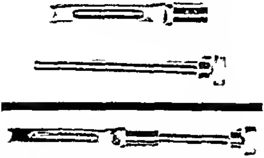


FIG 258 Hollow square mortising chisel and plunger used to destroy epiphyseal plate devised by White (Courtesy J Warren White)

Again let us suppose that this child had poliomyelitis in infancy which has resulted in 2½ inches shortening of one leg The short femur is 13 8 inches long or one inch short The short tibia is 11 inches long or 1½ inches short Teleroentgenographic studies with markers for a period of six months have shown that the epiphyses of the short femur were growing at 90 per cent of the rate of the normal femur and the epiphyses of the short tibia were growing at 80 per cent of the rate of the normal tibia From this we calculate that the short femur will grow 3 4 × 90 per cent or 3 1 inches to a final length of 16 9 inches The short tibia will grow 1 9 × 80 per cent or 1 5 inches to a final length of 12 5 inches The present discrepancy of 2 5 inches will increase to a final discrepancy of 3 2 inches As the normal femur will grow 2 4 inches from the distal epiphysis and the normal tibia will grow 0 8 inch from the distal epiphysis immediate fusion of these epiphyses will result in equality of length at full growth

It is also possible to perform epiphyseal arrest so that the knees will be of equal height For instance, the present length of the normal tibia is now equal to the final expected length of the short tibia Therefore fusion of the upper and lower tibial epiphyses will place the knees at the same height Equalization can then be gained by arrest of the distal epiphysis of the normal femur at a later date when the length of the normal femur approaches the final expected length of 16 9 inches of the short femur This is determined as follows The normal femur is already 14 8 inches and should grow only 2 1 inches to attain a length of 16 9 inches Of the 3 4 inches of expected growth of the normal femur, 30 per cent or one inch is contributed by the upper femoral epiphysis which cannot be fused Therefore the growth allowed from the distal femur will be 1 1 inches During this growth the whole femur will grow 100/70 × 1 1 or 1 6 inches therefore the distal epiphysis of the femur should be fused when the normal femur has grown 1 6 inches to a length of 16 4 inches

Epiphyseo diaphyseal Fusion (White) Under a tourniquet the epiphyseal plate at the lower end of the femur is exposed by medial and lateral longitudinal incisions An adequate subperiosteal dissection is made of the areas A hollow square mortising chisel (Fig 258) is used in the following manner It is placed diagonally across the epiphyseal line so that two of the points are forced into the epiphyseal cartilage and one into the bone above and one into the bone below The chisel is then driven to a depth of ¾ of an inch or more, directing it slightly distally in order to follow the more superficial portions of the metaphysis as it curves downward This direction is determined by an exploring skin needle The square plug of bone and cartilage is then loosened and the mortising chisel is rotated 90° so that the cartilaginous epiphyseal plate now lies in the long axis of the femur and solid bone on either side of it bridges across its former site The plugs are tapped into place by the plunger inserted into the chisel as the latter is withdrawn The wound is then sutured and a similar procedure carried out on the remaining half of the epiphyseal plate through the other incision and this wound

is in turn closed A circular plaster of paris bandage is applied for two weeks and weight bearing without support is allowed in four weeks A similar procedure may be applied to the upper or lower tibial and fibular epiphyseal plates if growth arrest is desired here In case the upper fibular epiphyseal plate is exposed care must be exercised to protect the peroneal nerve as it passes around the neck

Shortening of Lower Extremity by Resection of Bone Shortening of the lower extremity by resection of bone has been done for many years The shortening of the tibia and fibula and the femur have all been done but by common consent the femur is usually chosen Campbell has described an ingenious operative procedure for shortening both the *tibia and fibula* and the femur I am more familiar with White's *procedure* and *therefore, will present it* White states that the minimum discrepancy that he considers necessary for a shortening operation is two inches

Femoral Shortening (White) (Fig 259) A simple oblique angle osteotomy of the femur is done at the middle of the shaft The periosteum is meticulously separated for a distance of one inch beyond the desired amount of shortening of each fragment The bone ends are allowed to override to the desired shortening A Lowman clamp is then applied to the overlapping bone ends and these are fixed by vitallium screws placed one inch apart After suture of the *wound* a plaster of paris *spica is* applied from the toes to the costal border At the end of eight weeks the cast is removed, and weight bearing is allowed when union, checked by roentgenogram is reasonably certain A ringlock brace is used only if union is delayed White states that the quadriceps femoris relatively *lengthened*, regains sufficient tone to permit its holding the lower leg extended at the knee against gravity by the time the plaster spica is removed The knee joint may *be relaxed* but no permanent disability and no impairment in strength or usefulness of the leg have been noted

LESIONS OF ANTERIOR POLIOMYELITIS AFFECTING ABDOMINAL MUSCLES TRUNK MUSCLES AND SHOULDER GIRDLE

Paralysis of the abdominal and spinal muscles produces serious disability but treatment has been limited until relatively

Fig 259 Roentgenogram of shortening of femur after operation (Courtesy J Warren White)

recently to various types of support except for the correction of spinal curvature by the *wedging jacket and operative fusion* of the involved spine

Scoliosis or lateral curvature is a deformity of the spine which is not infrequently due to anterior poliomyelitis It occurs with other recognizable lesions which come as the aftermath of this disease and there are many who feel that so-called idiopathic scoliosis is due to otherwise unrecognized anterior poliomyelitis *There are, of course* other causes of lateral curvature of the spine such as *congenital* anomalies empyema, or paralysis of the paravertebral mus-

cles following thoracoplasty In those cases due to anterior poliomyelitis the curve is convex on the weak or paralyzed side and concave on the unimpaired or less impaired side There are, of course, compensatory curves above or below the primary curve Lateral curvature due to known anterior poliomyelitis is usually noted within a year of onset of the disease It progresses most rapidly during the years of rapid growth—12 to 14 years for girls and 13 to 16 years for boys

Correction of these curvatures due to anterior poliomyelitis which progress is imperative to prevent a markedly disfiguring deformity of the spine thorax and at times the pelvis The correction by wedging jacket is effective though arduous, and the maintenance of the correction is assured by a solid surgical fusion of the corrected area of the spine This subject of the treatment of scoliosis or lateral curvature is discussed elsewhere in this volume so I omit technical details [For details of treatment of paralytic scoliosis, see Chapter 6 —Ed]

Paralysis of Abdominal Muscles Attempts to correct or remedy paralysis of the abdominal muscles with resulting pelvic tilts by surgical means have been reported by Lowman F Dickson and Mayer One difficulty encountered seems to be an inability to be quite certain which muscles are at fault in spite of rather elaborate tests of muscle function Lowman has devised a fascial transplant operation for paralysis of the lower recti and obliquus abdominis muscle which consists in substituting a strip of fascia for the paralyzed rectus and a second strip of fascia extending from the upper rectus muscle obliquely downward to the opposite iliac crest where it is anchored to the ilium Mayer has used a modification of this procedure in anchoring the fascial strip to the ninth rib of the same or opposite side above and to the iliac crest below Dickson has used a fascial strip anchored above to the sacrospinalis muscle at the level of the twelfth thoracic vertebra and below to a tunnel in the iliac crest as far forward as possible to substitute for the paralyzed quadratus lumborum muscle These abdominal fascial substitution operations are useful in helping to stabilize tripod walkers

Other fascia anchoring operations have been devised to stabilize the scapula to the side of the thorax when, owing to paralysis of its various muscular attachments, it moves backward or forward

The opportunity and indications for those various fascial stabilizing operations on the trunk will not be frequent for most surgeons and the end results of those done will have to be carefully and extensively analyzed before these procedures may be unqualifiedly recommended for general use

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8

Treatment of Paralytic Disorders Exclusive of Poliomyelitis

WINTHROP MORGAN PHELPS M D

INTRODUCTION

The treatment of the paralytic disorders, exclusive of poliomyelitis is by combinations of medical, re educational, and surgical methods In some instances medical treatment alone is satisfactory and in others surgical and re educational measures are combined A discussion of medical treatment is not considered here, but surgical and re educational methods are so closely allied that they cannot be separated These disorders result from (1) Congenital anomaly (2) trauma at birth, (3) trauma following birth, or during later life, (4) disease of the central nervous system or muscles (5) toxic agents, (6) deficiency states, and (7) neoplasms

These conditions may arise in the brain, spinal cord, peripheral nerves, or in the muscles themselves It is obvious, therefore that there may be a general classification in terms of the *neurogenic* and *myogenic* type

Among the neurogenic types there are motor disturbances arising from damage to the brain and damage to the spinal cord as well as the peripheral nerves In the brain the damage may be of the nature of congenital anomaly, trauma at the time of birth or postnatal trauma toxic conditions resulting from prenatal toxemia disease such as encephalitis or degenerative disease, tumors, and possibly deficiency states In the spinal cord of course all these conditions may be duplicated but the results as regards a paralytic disorder may be different The same also may be true of the peripheral nerves

In the myogenic type, congenital disorders of the muscles such as myotonia congenita and acquired conditions such as myasthenia and dystonia produce definite paralytic disorders There are in addition also the degenerative conditions such as myasthenia gravis the dystrophies and progressive muscular atrophy

A complete classification of the entire field is unnecessary here since treatment consists of the correction or amelioration, if possible, of the resultant joint and muscle difficulty It is of great importance to eliminate the possibility of the progressive nature of the disease in which a downhill course is to be expected and thus eliminate from treatment conditions resulting from malignant tumors, degenerative diseases, and so forth It is likewise important to determine the presence of toxic states and deficiency states before attempting any corrective procedures

The treatment of these disorders is modified by a number of factors The age of onset—whether at birth during childhood, during adult life, or during old age—would bring about a definite modification of the type of treatment to be used Those cases in

which the condition has persisted since birth do not have any previously learned voluntary motor associated patterns, and these patterns must be developed if voluntary use of the extremities is to be attained By contrast, conditions arising during childhood or adult life represent disturbances of previously learned motor patterns and obviously the treatment would be greatly modified by this previous ability If the condition is acquired in old age such as a hemiplegia from cerebral accident the expectancy of life following the condition should be taken into consideration

A second factor of importance in treatment is the age of the patient when first seen Obviously surgical or corrective measures which would apply to adults could not be utilized in the infant and it would be important to determine how much change growth and physical development would produce A third factor would be the length of time which has elapsed since onset of the condition when the patient is seen If the time has been long during which the patient has been untreated there would be problems of muscle atrophy from disuse hypertrophy from overuse of other muscles muscle imbalance, and also contractures from use in a wrong position to be dealt with

A further factor of importance would be the degree of involvement This would cover the question of whether only one extremity or the entire body was involved and whether there was any hope of restoration to usefulness For example if the trunk and legs were so involved as to make the upright position impossible correction of the deformities of the feet would naturally be inadvisable and useless The mental status also must be considered under the heading of degree of involvement Finally the type and nature of the involvement is of great importance The central types of motor disturbance seen in this type of disorder can be classified under the following headings Flaccidity of muscles weakness of muscles, hypertrophy with or without increased muscle strength, involuntary motion, spasticity, rigidity, tremors, and balance disturbances

These types of muscle disorder cover practically the entire field of disturbance and it is extremely important to determine which type of disturbance is present They may, of course occur in combinations as well as individually True flaccidity, uncomplicated with other types of muscle disturbance, would be treated in the same way that the surgical treatment of poliomyelitis is carried out but flaccidity is frequently found in combination with spasticity in other muscles, as well as in combination with other disturbances which would modify and complicate the treatment to a considerable degree

It must also be borne in mind that there are frequently sensory changes complicating the motor disturbances in many of these conditions Thus, marked loss of sensation might render an arm relatively useless even in the presence of minor degrees of motor disturbance

Loss of kinesthetic sense also is of great significance in the ability to use an extremity in a normal way

The treatment of the paralytic disorders therefore, will be considered under the special headings of the types of motor disturbance rather than under the heading of disease or conditions since there is great duplication in many of the underlying causes

For example a birth injury which damages a certain part of the brain can give exactly the same motor picture as an encephalitis localized in the same area The treatment of the two would probably be very much the same and a repetition of treatment for one of these conditions when applied to the other would not be necessary The treatment will therefore be considered under three chief groupings

1 Spastic disorders
2 Disorders of involuntary motion
3 Disorders of balance

THE SPASTIC DISORDERS

Etiology and Pathology

Spastic disorders result from damage to the pyramidal tract in the brain or spinal cord. The pyramidal system may show congenital anomalies associated with microcephaly and other stigmata. There may be various types of damage to the pyramidal system at or around the time of birth. Cerebral anoxia, actual damage to the cortex by instruments, and rupture of the cerebral vessels in prematures are the chief factors. Severe paroxysms of coughing in early pertussis or rupture of vessels during a convulsive seizure represent two causes during infancy. In childhood trauma is the greatest factor. Automobile accidents, falls, and other types of injuries occasionally produce spastic states. The same is true of adults, and head injuries of all types are becoming more and more frequent with the use of automobiles and airplanes. War injuries can be responsible for spastic states when the cortex is injured. Beyond middle life and old age, arteriosclerosis and hypertension produce definite spasticity with considerable frequency. In the spinal cord, fractured spines, cord injuries, and wounds may result in spastic states.

The cortex, however, represents a rather widespread area including many differentiated functions within the pyramidal system itself. Thus, certain parts of the cortex when injured produce flaccidity of muscles while others produce definite spasticity in the sense that the muscles show a hyperactive response to any stimulus. The motor picture in the extremity involved therefore more frequently represents a combination of spastic and flaccid muscles with normal muscles intermingled than a picture of spasticity alone.

The fundamental principles of treatment depend very definitely on a careful evaluation of the muscular involvement and the relationship of spastic to flaccid muscles in the extremity itself.

The Spastic Foot

The foot can show almost any type of deformity. Resulting chiefly from spasticity of the muscles of the calf, the deformity may be influenced by involvement of [illegible] of the thigh and pelvis. The chief deter[illegible] in the foot are equinus position [illegible] position, and marked varus or val[illegible] combination of these. The assumption [illegible] these positions by the patient, however, [illegible] not always represent the same type of [illegible] cle involvement. Thus, the equinus positi[illegible] may be the result of a highly spastic heel cord group or may be equally marked [illegible] cause of a flaccidity of the dorsiflexors [illegible] the foot. It is obvious that the treatment would be modified by this difference in muscle involvement. In occasional instances also a marked equinus may result from a very low degree of spasticity in a leg which has not grown normally and is shorter than the other.

If the spasticity is due to a highly spastic heel cord, then a careful determination of the power in the dorsiflexors must be made in order to determine the result which will be obtained. If the dorsiflexors appear to have normal power but are blocked in their action by the spasticity of the heel cord, there are a number of procedures which may be carried out on the foot. The question as to whether clonus is present or absent in the foot also modifies the treatment. If no clonus is present, a simple heel cord lengthening may be considered, provided there is not spasticity present in the dorsiflexors. If spasticity is present in the dorsiflexors, however, the foot will be immediately converted into a calcaneus position due to the free action of those muscles. This is a disastrous result.

If clonus is present, a neurectomy of a partial nature on the branches of the popliteal nerve to the gastrocnemius or soleus would result in its elimination. It must be borne in mind that to some extent this weakens the power in the heel cord and

therefore some branches must be left to carry out the activity of plantar flexion which is so important to proper standing balance and walking

Occasionally an equinus position is seen in which the spasticity is in the flexors of the toes and not in the gastrocnemius soleus In this case, of course a lengthening of the heel cord would not produce the desired results In other instances it is found that the tightness in the heel cord is due not to spasticity but to flaccidity of the dorsi flexors with a contracture of the sheath of the gastrocnemius rather than the muscle itself

The procedures therefore which can be used in a spastic foot with regard to nerve muscle relationship are partial neurectomy, tendon lengthening tendon sheath lengthening and combinations of these

In children it is well to bear in mind that frequently there is a great tendency for shortening of the heel cord if there is any spasticity present because of the growth in the length of the tibia and the position of the child during sleep The foot is almost invariably held in extreme plantar flexion during sleep and it is during this time that a great deal of the shortening occurs It is more important to use a night brace or splint to hold the foot in as good a position as possible during sleep than to apply a brace during the daytime In many instances a beginning equinus position may be overcome simply by the use of a night splint or brace where the use of the brace during the day time has not held the condition in check A simple posterior plaster molded splint adequately padded and holding the foot in proper position will usually meet the requirements

Except in cases of marked contracture in growing children it is better to use conservative measures as long as possible before resorting to operation so that the maximal growth in a limb may be reached before the surgical correction is made It may be stated therefore that in equinus deformities of the foot, conservative measures with night splinting are to be recommended in growing children before resorting to any surgical procedure The handling of equinus deformity by surgical methods is dependent entirely on the relationship between the power (which may be masked) in the dorsi flexors and the degree of spasticity in the heel cord

Bony operations are frequently necessary either by themselves or in connection with the muscle nerve procedure These operations represent a fixation of the tarsus by any of the better known methods which are described elsewhere in relation to poliomyelitis [See Chapter 7 —Ed] If the spasticity involves the flexors of the toes a great deal can be accomplished by fixation of the midtarsus in order to bring about a more direct action of the muscles on the foot as a unit Of course these operations are of still greater importance where the equinus position is complicated by varus or valgus deformity

Calcaneus deformity in the foot of the spastic type is very difficult to control It is frequently seen as the result of ill advised heel cord lengthening but occasionally occurs as a primary condition in marked spasticity of the dorsiflexors of the foot and a corresponding flaccidity of the gastrocnemius and soleus Calcaneus position seldom occurs in the spastic foot without a flaccidity of the heel-cord muscles The pull of gravity reinforced by a normal or even moderately flaccid heel cord does not usually allow the position to develop even in the presence of spastic dorsiflexors Calcaneus is however, almost a universal result of heel cord lengthening in the presence of spastic dorsiflexors It is practically impossible to correct the deformity by means of conservative methods The operative correction embraces a group of various procedures

In the first place it is well to partially neurectomize the muscles of the dorsiflexor group The heel cord should then be

shortened by any of the accepted methods [For technics of tendon shortening see Chapter 42 —Ed] It is frequently of great assistance to suture the tendon of the flexor hallucis longus or the flexor digitorum longus or both, to the shortened heel cord in order strongly to increase the flexor power in these groups A bony correction of the foot may be necessary by a wedge osteotomy through the astragalus or the use of other bony operations of accepted types [See bone operations for pes calcaneus Chapters 3 and 7 —Ed]

Varus and Valgus Deformities

These deformities may be due either to a spastic flaccid imbalance between the peroneals and the tibials or to an imbalance in the muscles of the hips resulting in a gait of either extreme internal or external rotation of the leg If the condition is due to muscle imbalance between the peroneals and tibials carefully selective neurectomy of the nerves to the spastic muscles with lengthening of the muscles themselves if contractures are present may obviously be of benefit But stabilization of the foot is necessary in most cases When the condition is due to imbalance in the hip rotators the treatment should be directed to the hips as will be described later, rather than to the muscles of the foot although a stabilization may be necessary if deformity of the tarsal bones has resulted from long continued use in the abnormal position

The surgical procedure for neurectomies can be described as follows The trunk nerve from which the branch to the muscle under consideration arises should be exposed at or about the point where the branches are given off Tests are then made of the branches either by means of the electric current, or by gentle pressure on the various branches by smooth forceps It has been found that gentle squeezing of the nerve produces no harm in regard to future function, if done with care

Observations of the muscles under consideration by the surgeon are then made and the response to each of the nerve branches is determined In this way the branch which is especially responsible for clonus or high degree of spasticity can be easily identified The branch may then be cut off at its origin from the trunk nerve and avulsed from the muscle by winding it around a clamp This has proved to be the best procedure since either to simply cut the nerve or to take a section out of it has been known to allow of regeneration Actual avulsion of the nerve from the muscle does not allow of any regeneration so far as has been observed If there is doubt at operation as to the efficacy of neurectomy of a particular branch alcohol injection will produce the effect for a period of several months but power will eventually return Alcohol injections are sometimes used instead of neurectomies where there is an intention to develop power in antagonists while the involved muscle is temporarily thrown out of function This is based on the idea that by the time the power returns to the treated muscle sufficient strength will have been developed in the antagonist to produce better balance But alcoholization of the nerve is much more valuable as a therapeutic indication for eventual neurectomy in cases of doubt

It is seldom wise to carry out a complete neurectomy of all of the nerve power to a given muscle without very careful consideration as regards the result This is especially true in the gastrocnemius soleus combination The chief indication for neurectomy is the presence of clonus in this muscle and it must be determined before neurectomy whether the clonus arises from the gastrocnemius or from the soleus This can be determined with some degree of accuracy by observing the clonus with the knee in different positions The gastrocnemius heads arise from the femur above the knee and they are definitely relaxed by flexing the knee In cases in which the clonus is in the gastrocnemius therefore, the clonus will be

found to disappear or be greatly diminished by flexing the knee However, in cases where the clonus arises from the soleus muscle the position of the knee has no effect whatever on the type or degree of clonus since the soleus arises below the knee joint The nerve to be avulsed therefore should be selected from nerves to the gastrocnemius or soleus depending upon the type of clonus in cases where this procedure is designed to eliminate clonus alone

In markedly clonic cases it is not advisable to carry out a heel cord lengthening at the time of neurectomy until the patient s gait has been observed after the elimination of the clonus as the heel cord lengthening may definitely not be necessary and might bring about a great weakening of the muscle and perhaps a calcaneus position

Neurectomy for clonus is an especially valuable procedure in spasticity resulting from cerebral accidents from hypertension since the procedure itself is not severe, and the age of the patient, being usually advanced, would not warrant any extensive operative undertaking In many instances, the gait can be restored very greatly in older people by a simple neurectomy for clonus, since this is one of the factors that seriously interferes with these patients ability to walk

The Spastic Knee

In this joint there is a relatively simpler problem than in the foot, but the weight bearing function of the knee resulting as it frequently does in flexion, and the tendency to sit for long periods with the knees flexed, brings about a real problem with regard to control of this very common deformity As is the case in all other situations, careful thought must be given to the relationship between the power present in the flexors and extensors The quadriceps may be spastic, flaccid, or normal, and the essential flexors the hamstrings, may also show any of these three types of power A flexion deformity may be due to weakness of the quadriceps in the presence of normal, spastic, or even flaccid hamstrings, if the patient is accustomed to long sitting If this is the case, he probably sleeps with the knee in flexion at night Attempted weight bearing under these circumstances will of course result in a tendency for a stretching of the tendon between the patella and the tibial tubercle In such cases it is possible to bring about a great deal of correction by transplantation of the tibial tubercle to a point lower in the front of the tibia [This is a relatively simple procedure Through a longitudinal curved incision to one side of the tibial tubercle, the patellar tendon, the tibial tubercle, and the tibia below it are exposed The patellar tendon is freed by dissection of its medial and lateral margins, and the tubercle with the attached tendon is removed en bloc with a sharp thin osteotome At the desired distance below the normal attachment the periosteum of the tibia is incised and reflected to each side to expose tibial surface A block of tibial cortex the size of the tibial tubercle block is removed, and the tubercle block with its attached tendon is countersunk into the opening, the reflected periosteum being sutured back over the area and to the patellar tendon The bone removed from the lower area is used to fill the defect created by the removal of the tubercle A plaster encasement in extension is worn until adequate healing has occurred—six to eight weeks —Ed]

However, unless the underlying cause of this difficulty is removed, that is, the cause of the flexion, further stretching of the patellar tendon will take place and the leverage will again become bad

A spastic quadriceps may bring about a stretching of the patellar tendon simply because of the frequency of the spastic contraction in this muscle On the other hand, a weak quadriceps may allow of stretching of the patellar tendon if there is spasticity in the knee flexors It can be seen that the treatment under the two conditions de-

scribed would be very different In the first case probably very little would be attained by patellar tendon advancement as the tendon may again stretch postoperatively, unless, by appropriate measures, the muscle clonus or spasm could be diminished In the second place, transplantation of the tibial tubercle downward would result in further stretching of the quadriceps unless the spasticity was reduced in the hamstrings This spasticity may be reduced either by lengthening the hamstrings or by partial neurectomy of some of the nerve branches to the hamstrings to reduce their power This must of course be done selectively in order to bring about as balanced a pull of the hamstrings as possible

In some instances the flexion deformity is complicated by contracture of the posterior knee joint capsule if it has existed for a long period of time In this case a capsuloplasty of some type must be done in order to allow full extension of the knee

If these operations are performed during a rapid period of growth in a child there is a great deal more tendency for recurrence to take place than if they are carried out during early adolescence If they do have to be done earlier it will be necessary to apply a caliper splint or other type of brace to be worn at night in order to prevent recurrence of the flexion deformity

In some instances the flexion at the knee is the result of adduction and internal rotation deformity of the hip with a very strong pull by the tensor fascia femoris In other cases there is weakness of the abductors of the hip and the gluteus medius, so that the patient attains standing balance only by pressing the knees firmly together in some degree of flexion Obviously no operative procedure about the knee will correct a flexion deformity that is due to this hip condition

In other instances there is a tendency toward hyperextension of the knee, rather than flexion, in the spastic This hyperextension is again the result of imbalance of the muscles and is frequently due to a tight heel cord When the patient attempts to bring the foot to the floor the knee is forced back into hyperextension This of course could not happen in the presence of any very great degree of spasticity in the hamstrings since a stretch reflex would be brought about in the hamstrings resulting in a flexion of the knees even if the patient was able to stand only on the toes But in cases where the hamstrings are relatively normal or show some evidence of weakness and also in cases where the quadriceps is highly spastic there is frequently this tendency to hyperextension of the knee

In cases of this sort first attention must be given to the nature of the foot difficulty Great care must be exercised in a decision as to lengthening of the heel cord with the resultant instability in the knee In some cases the quadriceps is not strong and even though hyperextension takes place from a tight heel cord the result of tenotomy would be a greater instability in standing than was present before the heel cord had been lengthened

Occasional cases are seen in which there is such an imbalance in the spasticity of the hamstrings as to produce a severe varus or valgus deformity in the knee in attempts to stand A valgus deformity may also be produced by excessive tightness of the tensor fascia femoris, and in these cases the use of braces is almost essential after surgical operations to balance the knee in regard to its lateral stability However, once the tension has been released an exercise program might bring about a gradual tightening of the lateral ligaments of the knee and a greater degree of stability, so that braces might in some cases be eventually eliminated

The Spastic Hip

The hip region in the true spastic is represented by a wide degree of diversified deformities The most common one is flexion and internal rotation This is very

is lost and the patient cannot stand alone If the adductors are cut or neurectomized and there is no power in the abductors the patient naturally loses his lateral balance and cannot stand alone without falling to one or the other side It is therefore, important to determine that there is good power in the abductors before considering any form of operation on the adductors Adductor tightness is frequently not spasticity but simply contracture due to weakness of the abductors

If power has been shown to be present in the abductors and a procedure is to be carried out on the adductors then the tenotomy of either the pectineus and adductor longus or the adductor brevis and magnus is better than a tenotomy of all the adductor muscles A differential test should be made to determine which of the muscles are the tightest and to cut these rather than to cut them all

When an obturator neurectomy is carried out it may be done either at the point of entrance into the muscle or higher above the pubic ramus

Flexion deformity in the hip has been described above as being associated with internal rotation if the tensor fascia femoris is tight This flexion deformity may also be due to tightness of the sartorius and rectus femoris as has been described In a few instances however it is due to tightness or spasticity in the iliopsoas In cases of this sort it is well to see that there is power in the rectus femoris and sartorius before attempting any operative procedure on the iliopsoas itself

In some instances where the spasticity has been proved by testing to be in the iliopsoas muscle this can be released through an incision posteriorly in the gluteal fold with the leg rotated inward so as to throw the lesser trochanter back The incision is made down to the lesser trochanter and the iliopsoas attachment may be pushed loose from this It does not have to be sutured in any particular place but will reattach itself higher up and perform some function This can be done only in the presence of good power in the sartorius and rectus femoris It is possible to determine that spasticity is present in the iliopsoas only by exclusion of the other hip flexors If the leg is pulled sharply down from the flexed position with the patient lying supine and there is no stretch reflex observed in the sartorius or rectus femorus which can be readily felt then it must be assumed that the stretch reflex obtained arises from the iliopsoas Very few cases of spasticity of the iliopsoas have been observed The spasticity is usually in the superficial flexors—the sartorius rectus femoris and tensor fascia femoris

The other three essential deformities of the hip—extensor tightness abduction tightness and external rotator tightness—are relatively rare However a number of cases of external rotator tightness or spasticity have been seen and these are best handled by a loosening of the attachment of the external rotators to the greater trochanter posteriorly Here again it is necessary to determine that there is internal rotator power in the hip or stability will be so lost that the patient will be unable to stand after the release of these muscles The same procedure can be applied to the top of the greater trochanter where there is spasticity of the abductors if power has been proved to be present in the adductors

As can be seen from the above in every instance where an attempt is to be made to overcome spasticity or tightness the nature of the power in the antagonist to the muscles under consideration must be worked out first and this will determine the type of operative procedure which is advisable

In instances where the power is not satisfactorily determined, for example in a hip externally rotated in which there is not sufficient internal rotator power it has sometimes been advisable to carry out an osteotomy of the femur below the attachment of the rotators and bring the thigh and

frequently mistaken for an adduction deformity and must be carefully differentiated from it It has been thought in the past that adduction in the hip produced the scissors gait but it is much more commonly produced by internal rotation and flexion This internal rotation is most commonly the result of tightness of the tensor muscle of the fascia lata This muscle rises from the region of the anterior superior spine and passes diagonally backward pulling on the fascia lata and thus rotating the leg inward By nature of its origin from the front of the pelvis it is also a flexor and is the chief cause of the scissors gait by virtue of the fact that the flexion allows one leg to cross the other Straight adduction might bring the legs together but unless the flexors were involved it could not of itself cross them

The other internal rotators of the hip are the anterior half of the gluteus medius and the gluteus minimus The best method of attack on the internal rotation deformity is the release of the tensor fascia femoris muscle Releasing this muscle will bring about a great degree of return of power in the external rotators and does not produce a weakening of the abductors or the anterior half of the gluteus medius An alternative operation is to release the anterior half of the gluteus medius but this does bring about some weakening of the power of abduction and hence occasionally results in a positive Trendelenburg and a tendency to a swaying gait It is difficult to distinguish between spasticity in the tensor fascia femoris and the anterior half of the gluteus medius but in a large series of cases it has been found that spasticity of the gluteus medius is relatively rare The best method of release of the tensor fascia femoris is to detach it from its origin on the crest of the ilium and simply allow it to slide down It may be sutured posterior to its original position if this seems desirable but in many instances the simple release without any further attachment will produce a very satisfactory result There is in some cases a secondary tightness of the sartorius and rectus femoris When these muscles appear tight they of course may also be released from their origin and allowed to reattach farther down on the pelvis if flexion is a large element in the difficulty with the hips [For hip-flexion deformity procedures see Chapter 7 —Ed]

It might be said at this point that a neurectomy of the nerves leading to the tensor fascia muscle appears to be unsatisfactory, as the muscle is frequently contractured as well as spastic and would have to be loosened in some manner Once it has been loosened there is no particular point in the neurectomy

The true adduction of the hips is entirely a different problem Here a test must be made to see that when the legs are forcefully pulled apart no tendency to internal rotation takes place If they can be forced apart without internally rotating and the adductor tendons can be felt to stand out strongly, there is every reason to believe that the condition is chiefly an adductor spasticity or contracture This is as has been pointed out before less common than the internal rotation deformity When the adductors are tight the choice of procedures is between a tenotomy and an obturator neurectomy It is seldom necessary to do both since tenotomy cuts out the muscle pull in any case and neurectomy then is not necessary

Before carrying out any procedures on the adductors however it is important to determine that there is sufficient abductor power to hold the legs apart when they have been pushed apart There are a number of patients who could previously walk by pressing the knees together relying on the spasticity in the quadriceps for support but who after adductor tenotomy, were no longer able to walk at all due to weakness of the gluteus medius or abductor muscles Power in the abductors or gluteus medius is essential to standing balance and when these are weak or paralyzed lateral balance

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In instances where the power is not satis factorily determined for example in a hip externally rotated in which there is not suf ficient internal rotator power it has some times been advisable to carry out an oste otomy of the femur below the attachment of the rotators and bring the thigh and

leg into better alignment so as to utilize these muscles in their shortened positions This is done only in cases where there is more power in the opposite or antagonistic muscles and where correction by muscle loosening or neurectomy cannot be utilized

In the leg as a whole osteotomy of the tibia is occasionally necessary to correct a rotation which has occurred from an abnormal spastic pull either in the peroneals or tibials The osteotomy is best done in the upper third of the tibia since union is more likely to take place quickly here than in the middle or lower third This osteotomy may be performed in a number of ways but the use of a Gigli saw is very satisfactory This should be used subperiosteally insofar as possible In the femur the osteotomy should be done about an inch below the lesser trochanter and certainly below the attachment of the rotary muscles of the hip

In some cases of spasticity a dislocated hip may be encountered X rays will determine whether there is sufficient acetabulum present to warrant an attempted reduction Before reduction is attempted however a careful muscle study must be made to determine the cause of the dislocation The dislocation usually occurs during infancy or early childhood but is not the typical congenital dislocation of the hip It occurs when the spasticity becomes sufficiently strong to pull the head of the femur out of the socket by flexion internal rotation and adduction The dislocation is usually a posterior one and reduction will not be maintained unless the deforming forces have been corrected previously That is the tensor fascia femoris must be loosened or some of the adductors must be tenotomized and attention must be given to the degree of flexion which is present in the flexors If these conditions can be corrected then a reduction can be attempted by either the closed or open method as desired [See Chapters 4 and 35 for technic —Ed]

The commonest deformity of the legs in the spastic is internal rotation slight adduction slight knee flexion equinus of the feet and some supination This is the characteristic position in about 40 per cent of spastics in which both legs are involved In about 30 per cent the opposite picture is found in other words abduction of the hips external rotation hyperextension of the knees and calcaneus and valgus positions of the feet The other 30 per cent of spastics with both legs involved represent a combination of these two with the internal rotator flexion condition in one leg and external rotator extensor position in the other This latter group is the most difficult to handle since any correction used in one leg tends to twist the patient and the result is a loss of control of the body as a whole The only way in which to carry out procedures in these cases is to correct one leg at a time since otherwise no amount of plaster spica will hold the correction

This group frequently represents the type of spastic with trunk involvement of the scoliotic type There is rotation of the spine and frequently a marked lateral curvature of the C or S type This type of scoliosis is very difficult to handle since the spastic pulls in the legs are constantly tending to increase the degree of rotation of the spine It is probable that no amount of fixation of the spine either bony or by appliances will hold until such time as the leg pulls are corrected Frequently then nothing is necessary since the spine will tend to straighten after the cause of the difficulty has been removed

The treatment of scoliosis in the spastic patient depends on an analysis of the trunk muscles to determine whether there is a one sided spasticity which may frequently be seen in hemiplegic spastics or whether the pull is due to the positions of the legs as described Occasionally there is an imbalance in the abdominal musculature of the spastic producing a spasticity of one side of the abdomen and resulting in a rotary lateral curvature In very few instances neurectomy of some of these ab

dominal muscles has been carried out but without much success In other instances fascial transplants have been utilized to assist the weak side and to correct the deformity by this method [See Chapter 7 for operative technic —Ed] Spinal fusion and spinal grafts are satisfactorily used in the cases where the pull is not too strong It is almost impossible to carry out a neurectomy or any lengthening of the erector spinae masses since these muscles are too great in number and overlap each other to such an extent that no good effects can be produced by this method It may be said definitely that spinal fusion has a real place in these cases and that it is very effective provided the underlying causes have been noted and corrected in so far as possible If one of the difficulties is instability of the spine so that the patient is unable to hold the spine erect due to weakness or flaccidity of some of the muscles with overbalancing spasticity of the others the use of a brace or corset should be tried first to determine how much stability can be obtained by external fixation If this proves satisfactory then a fusion is definitely indicated [See Chapter 6 on scoliosis and treatment therefor —Ed]

The Spastic Arm

The arm of the true spastic may have any type of combination of muscle weakness muscle spasticity interspersed and normal muscles from the fingers to the shoulder However several characteristic positions have been observed which can be recognized as more frequent than the other positions The first of these is finger flexion wrist flexion pronation elbow flexion and internal rotation of the shoulder This is the most common position seen in the spastic arm The second most common is the exact opposite with hyperextension of the fingers supination and adduction and external rotation of the shoulder with elbow extension In this case the arm is held usually down at the side with the elbow straight and the palm turned forward The fingers are frequently flexed in the distal joints but are hyperextended through their proximal joints This position and the first one described are also frequently seen in brachial palsies of the lower motor neurone type resulting from damage to the brachial plexus at birth But of course in spastics they are much more complicated

In dealing with the arm of the spastic surgically it is well to bear in mind that each joint must be considered in relation to the function of the other joints It seems most satisfactory to consider the shoulder first and obtain good control of this in positions where it will make useful the elbow wrist and hand rather than to begin with the hand and from thence to work up to the shoulder

The most common deformity in the shoulder is internal rotation due to tightness or spasticity or both in the subscapularis Before attempting any procedure on this muscle the status of the external rotators must be determined If power can be demonstrated in these muscles by bringing the arm into external rotation and getting the patient to hold it in that position then treatment of the subscapularis is advisable In this region it has been found that neurectomy is difficult but tenotomy of the subscapularis has frequently been very effective If there should be spasticity present in the infraspinatus also an extreme externally rotated position of the shoulder would result which would not be desirable However an internal rotator deformity in the shoulder in the presence of a balanced spasticity between the internal and external rotators is very rare If the external rotator or infraspinatus proves to be flaccid or practically functionless then of course a recurrence of internal rotation deformity would probably take place due to action of the teres major even after tenotomy of the subscapularis In cases where there is spasticity present in the latissimus dorsi or in the pectoralis major lengthening of the

tendons is more satisfactory than tenotomy It is advisable to allow them to retain some of their power since they act as stabilizers of the shoulder and are very useful in this respect The lengthening of these tendons brings about an increased weakness of their function and hence balances up the power in the deltoid which is so essential to good use of the shoulder

With regard to the scapula itself spasticity is seldom seen involving either the serratus anterior or the rhomboids alone Spasticity is usually well balanced between these muscles when it is present in either of them In some instances they both present some degree of flaccidity in which case the control of the shoulder is poor but in most cases it is a balanced situation Winging of the scapula on abduction of the arm due to weakness of the rhomboids the trapezius or both is not often seen in the spastic arm When it is it is usually due to an underlying scoliosis with rotation of the ribs posteriorly bringing the scapula out and thus decreasing markedly the mechanical advantage of the rhomboids in control of this function There is very little that can be done in case of imbalance of the scapula but these cases are so rare that the significance of this particular difficulty is relatively slight

The Spastic Elbow

In the elbow there is a great deal of variation in power in the biceps and brachialis anticus in relation to the triceps Spasticity may be found in all three muscles in which case the function of the elbow is slowed by a stretch reflex in both directions In this type of elbow it is unwise to carry out any surgical procedure The best therapy is gradually to work up the speed of flexion and extension of the joint by an exercise program Over a period of months this will definitely increase the speed and a great deal of improvement can be made In cases where there is spasticity of the biceps or brachialis anticus the important point is to determine whether the triceps is normal or is weak or flaccid If there is normal power in the triceps then a partial lengthening of the biceps may be carried out through its tendon or the brachialis anticus may be lengthened if at the time of operation it proves to be the offending muscle In some instances a neurectomy of either biceps or brachialis anticus can be carried out but a neurectomy of both should never be done since all flexor power would thus be lost In cases in which the triceps is involved and in which the biceps is normal or weak the arm is usually held in a straight position and there is difficulty in flexing the elbow In these cases a neurectomy of one of the nerves to the triceps has been carried out with some measure of success although this is a relatively difficult situation to deal with so far as is known at present The triceps tendon is so broad and is inserted in such a way that a lengthening of the tendon is very difficult and lengthening of the muscle belly itself is hard to carry out since the muscle is widespread over the back of the humerus In many instances it is best to utilize an elbow brace which will hold the arm in flexion except at such times that the patient wishes to extend it This can be adjusted by means of a lock on the brace at 90° or some other convenient position in which the patient can unlock the joint with the other hand and allow the elbow to be extended when he wishes

The Spastic Forearm, Wrist, and Hand

Pronation due to spasticity of the pronators is frequently seen in the spastic and is one of the major difficulties to be overcome in this type of patient Before considering any surgical procedure it is well to remember that supination while a very desirable function in the right hand is not nearly so necessary in the left Most of the articles requiring supination are for a right handed world and it is necessary therefore

for left handed people to bring about the winding of watches, opening of doors, turning of keys and so forth by a pronation motion of the left arm Therefore a persistent pronation of the left arm need not necessarily be corrected whereas it is of great importance to have supination power if possible in the right arm

Again, before deciding on the procedure to be carried out it must be determined how much underlying power there is in the supinators and to what degree the patient may be able to supinate the hand if the pronators are released The usual offending muscle is the pronator teres, and if power can be demonstrated in the supinators by bringing the hand into a position of supination and then asking the patient to hold it there it can be decided that a procedure may be carried out on the pronator teres The tendon of this muscle is difficult to reach and neurectomy is not very satisfactory because of the difficulty of finding the nerve to it

The most satisfactory procedure has been found to be an exposure of the entire pronator teres muscle and after opening the sheath dividing the muscle longitudinally into about six strips These strips of muscle are cut alternately at their proximal and distal ends The hand is then forcefully supinated allowing the strips of muscle to pull out like fingers This can be accomplished much more easily than might seem possible at first and there is very little bleeding probably because of the tendency of a muscle to contract and control its own bleeding This same procedure may be used on many other muscles it is difficult to apply to a very large muscle but is especially satisfactory in the smaller muscle groups

In many spastic wrists there is a tendency to ulnar deviation and flexion, and as the origin of the flexor carpi ulnaris is quite closely associated with the pronator teres, it can be easily lengthened by the same procedure at the same time The flexion deformities of the wrist lend themselves to some extent to muscle transplantation of the flexors to the extensor side and vice versa, but lengthening of the tendon is often satisfactory [For technics see Chapter 7 —Ed]

Neurectomies to the muscles of the forearm are difficult to accomplish It is much easier to work on the muscles themselves or to transplant them as indicated

In the use of tendon lengthening a great deal can be accomplished if there is power present in the antagonist of the spastic muscle In many cases the contractural element is the important one rather than the spastic element, and by lengthening these muscles the antagonist can gain sufficient mechanical advantage to bring about a much greater development of power by training after operation [For technics of tendon lengthening see Chapter 42 —Ed]

Fixation of the wrist by arthrodesis of any accepted type is a very helpful procedure in producing greater facility in the use of the muscles activating the fingers Wrist motion is relatively unimportant in relation to all of the other motions of the arm and a fixed and stable wrist will sometimes bring about a very useful hand when otherwise the action of the muscles of the fingers is taken up in the wrist resulting in a flexion deformity and little use of the fingers [For technics see Chapters 7, 14 15, and 33 —Ed]

To determine the effectiveness of an arthrodesis of the wrist it is important first to apply a brace which will accomplish the same result and to train the patient with this brace for a period of time to determine the effectiveness of it and the eventual results which may be obtained if an arthrodesis of the wrist is carried out

The Spastic as a Whole

The spastic patient must be considered as a whole with regard to total function to be attained in any given instance Many operative procedures have been described

above, and these, associated with careful muscle re education and training both before and after the operation will produce very favorable results

However it must be borne in mind that frequently the trouble with the spastic patient is not concerned with either the ability or lack of ability to move but is a disturbance of the speed with which contraction can take place The blocking of a given motion produced by the presence of spasticity in the antagonistic muscles to this motion brings about a slowing of the motion An example is the dorsiflexion plantar flexion power in the ankle A given patient may have a spastic heel cord and yet under exercise conditions may be able to bring the foot up into a good dorsiflexion position However this act is accomplished in many instances too slowly to be useful in walking The patient cannot bring the foot up quickly enough to clear the ground for his next step

During very slow walking the foot can be brought up well and the walk may be almost perfect But when the speed of walking is increased the motion no longer can take place and the foot is maintained in a toe walking position Unless the speed of dorsiflexion can be increased no amount of surgery will bring about any improvement in the gait This increase in the speed of muscle contraction can be attained only by a very careful exercise program usually utilizing a metronome or other timing device so that the muscle contractions may be gradually speeded up at a regular rate and greater speed of dorsiflexion thus attained As the voluntary speed increases the gait will be improved at faster and faster walking speeds In the spastic patient as a whole therefore the emphasis must be put on first the decision as to what types of improvement are to be attained and second on an exercise program as necessary both before and after operations The operations are not of themselves curative but are merely steps in a program of muscle re-education and training which the spastic must undergo

In very young spastics it is not wise to consider surgery except in the presence of extreme deformities But the exercise program should be carried out thoroughly in order to allow as much growth as possible to take place before resorting to surgery

INVOLUNTARY MOTION—ATHETOSIS

Up to this point only true spasticity has been considered The presence of involuntary motion as opposed to stretch reflex is found in almost as many cases as is spasticity It is frequently mistaken for spasticity since most patients with involuntary motion or athetosis tend to control this by voluntary tension They try to prevent the involuntary motion by holding the arm or leg as still as possible This voluntary tension eventually becomes habitual and the extremities may assume any of the positions which are seen in the true spastic It is very important to distinguish between this voluntary tension which has become habitual and which in some cases cannot be overcome voluntarily any longer and true spasticity This differentiation can be made only by testing the individual joints for a true stretch reflex The stretch reflex is tested by attempting to change the position of the joint rapidly by passive manipulation If there is a sudden tightening of the antagonistic muscles which tends to prevent motion then spasticity is present If, however there is a constant and continuous pull similar to voluntary resistance then there is probably habitual tension and not spasticity present

The nature of involuntary motion has been little understood and is still a very complicated problem It appears to be more an attempt to bring an extremity into a given position by any muscle which can be utilized than to be a disturbance of motion of any specific muscle The reason for this conclusion as regards involuntary motion is

based upon cases of this type which have been subjected to neurectomy, muscle transplantation, tendon lengthening, and such procedures, with resultant failures It has been found that when a muscle has been transplanted, for example, the involuntary motion does not shift with the transplant to the opposite direction, but persists as before, merely bringing into play other neighboring muscles which can accomplish the same or nearly the same result In a case of bony fixation below the ankle to prevent a varus deformity due to involuntary motion, the result showed eventually a tendency for the whole leg to go into an internally rotated position, as if there were an attempt to assume this position of varus even though the tarsus could no longer move In innumerable instances this type of poor result has been seen in cases with involuntary motion with all the various procedures described, although they have been very successful in true spastic paralysis

An illustrative example is that of a patient who had a flexion and internal rotation of the hip due to involuntary motion which was thought to be due to spasticity in the tensor fascia femoris muscle This muscle was released, but subsequently a varus deformity began to develop in the foot In another instance, in which the flexors of the wrist were transplanted to the dorsum for a persistent flexion involuntary motion, the resultant picture was still a flexion involuntary motion utilizing the profundus and sublimus flexors of the fingers instead of the wrist flexors as had been previously observed

These are examples of the difficulties arising from the ordinary orthopedic surgical procedures on patients with involuntary motion or athetosis They are almost always unsuccessful, and this type of surgery is therefore not advised in any of these cases

Of course, if true contractures can be demonstrated, as from long sitting with the knees flexed for a period of years, these contractures may be corrected as in any other case

There are at present a number of operative procedures which have been described by Putnam, Bussey, Klemme, and Meyer and Browder which deal with involuntary motion and tremor These operative procedures are carried out on the cortex basal ganglia, or the lateral columns of the spinal cord Results in them have been very favorable and these procedures are being perfected at the present time, but are as yet in a developmental stage They belong of course, in the realm of neurologic surgery

Involuntary motion whether in the form of athetosis or tremor, is susceptible to reeducation The use of relaxation therapy following one of the better known methods such as that of Jacobson, produces really remarkable results if persisted in over a long enough period of time, and it is advisable in these instances to utilize these forms of therapy and follow them up with motion from the relaxed position

DISORDERS OF BALANCE

In cases of cerebral injuries resulting in ataxia, there is of course no surgical procedure which is of any particular value, except as directed toward contractures if they are present These cases also are very susceptible to training by careful instruction in voluntary balance methods which eventually become habitual

Treatment of both involuntary motion and ataxia must of necessity be carried out over long periods of time in order to bring about satisfactory results and, when so treated, the end results are very favorable

OBSTETRIC PARALYSIS (ERB S BIRTH PALSY)

[The following account is written by the Editor]

General Features

This lesion, occurring as the result of a birth trauma which puts the brachial plexus

on the stretch during delivery, presents itself in three forms—(1) the so called upper arm type which comprises almost four fifths of the cases (2) a whole arm type which comprises about one fifth of the cases and (3) a lower arm type which includes the remaining few per cent Since early diagnosis and prompt institution of treatment are important in these cases and since the differential diagnosis of this condition from other birth injuries involving the upper extremity is sometimes not too easy in the newborn infant the essential features in diagnosis will be briefly presented

Any injury to the shoulder region during birth may give a pseudo paralysis due to the infants instinctive refusal to use the extremity This is characteristic of clavicle fracture separation of the upper humeral epiphysis and fractures of the humerus

The upper arm type of obstetric palsy presents the following picture due to involvement of the fifth and sixth roots entering into the upper trunk of the plexus together with the suprascapular nerve from that cord and the branch from it which enters into the formation of the middle cord of the plexus

1 Inversion and adduction of the shoulder with the elbow rolled outward and forward and in extension
2 Some pronation of the forearm with the palm of the hand tending to look backward
3 Usually more or less weakness of the wrist and finger extensors (This may be complete in severe cases)

The whole arm type presents a completely flaccid extremity totally immobile and at first without the striking features of the above characteristic position It is due to involvement of the whole plexus the various trunks being involved to different degrees and often at different levels It is impossible to demonstrate the sensory loss present

The rare lower arm type presents a definite syndrome known as Klumpke palsy The intrinsic muscles of the hand and the wrist and finger flexors are paralyzed as a result of damage to the lower trunk comprised of the eighth cervical and first dorsal roots Because of the involvement of the latter root and its sympathetic fibers however certain characteristic eye signs are present They are narrowing of the palpebral fissure drooping of the upper lid and contraction of the pupil

Prognosis The diagnosis of the exact type carries with it a prognostic import While recovery in any case is dependent in part on the severity of the actual pathologic process in the neurologic structures the upper arm type carries by far the best prognosis the whole arm type only a fair prognosis while the lower arm type has a rather hopeless prognosis under any form of treatment

In addition to the pathologic condition present in the nerve roots involved (which may vary from rupture of the perineural sheaths to partial or complete rupture of the nerve trunks outside the spine in the intervertebral foramina or within the spinal canal) there occurs a variable amount of hemorrhage and exudation susceptible to fibrous tissue organization in the supraclavicular region and in the axilla This is the explanation given by many for the later contractures which are found to occur about the shoulder joint and which must be guarded against in the early treatment and taken care of in the cases seen after they are established So marked is this tendency to contracture in some cases that the viewpoint has been advanced that there must be actual damage to the shoulder joint itself even to the point of dislocation posteriorly or of separation of the upper humeral epiphysis [For comment on traumatic birth dislocations see skeletal birth injuries Chapter 43 —Ed] Regardless of the viewpoint as to their cause, the importance of guarding against potential contractures or

of recognizing their existence in late cases is paramount in treatment

Treatment

1 The Neurologic Lesion It is today the consensus that the conservative treatment of early cases as described below should be adequately carried out for from four to six months before any direct attack on the neurologic lesion is contemplated If by that time there has been no demonstrable improvement and if either the amount of paralysis present justifies it or exact localization of the lesion in the more limited cases is possible operative exploration of the plexus may be considered It should be done by expert hands and is a surgical neurologic problem In the lower arm type and in many of the whole arm type it has often little to offer In the upper arm type *under the circumstances cited above* it is justifiable only in expert and skilled hands It is true that a few men have had some excellent results even in the early attack on the neurologic lesion But it is generally agreed today that such intervention should be limited to cases in which conservative therapy has failed to show response and in which the lesion is either hopelessly disabling or in which it is a definitely localized one of the upper arm type involving Erb s point—the junction of the fifth and sixth roots to form the upper trunk of the plexus including the suprascapular nerve given off here and the branch entering into the formation of the middle cord

2 Early Conservative Treatment—Upper or Whole arm Type As soon as the lesion can be diagnosed the child should be fitted with a supporting splint holding the extremity in the position lost as the result of the paralysis This can be homemade of plaster of paris of metal or of light padded wood or it may be a bracemaker s job It must be light in weight and comfortable enough so that the child is not obviously disturbed The extremity must be held in shoulder abduction at 90° or a little beyond and in as complete external rotation as possible with the elbow at right angles, the forearm in full supination and the wrist dorsiflexed with the fingers extended Failure to maintain at all times this approach to a Statue of Liberty position may allow the gradual development of contractures in shoulder adduction and internal rotation forearm pronation and wrist and finger flexion *It is important to remember that rather rapid recovery is oftentimes linked with early development of contractures if the recovery is more marked in one muscle than another* Signs of early muscle recovery therefore are not indicative of less urgent necessity for maintaining the extremes of the splinted position The splint should be worn at all times but the fastening holding the arm and forearm should be loosened several times a day and gentle massage given to forearm arm and shoulder muscles followed by circumspect and gentle forcing of the extremes of abduction and external rotation at the shoulder and of supination in the forearm and if the wrist extensors are affected of dorsiflexion at the wrist

When voluntary muscle action is observed the passive forcing of motion extremes may be supplemented by active motions in the desired directions by getting the infant to reach for brightly colored objects interesting toys etc —a primitive type of muscle re education When considerable muscle power has apparently been regained the splint is gradually and progressively omitted during waking hours but kept applied at night and during sleep at other times The passive but gentle forcing of the motions described above and the massage should be continued but more and more attention should be devoted toward eliciting active motion and function use of every sort from the child

Under this regime in favorable cases steady improvement may be noted resulting eventually in a degree of recovery

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When voluntary muscle action is observed, the passive forcing of motion extremes may be supplemented by active motions in the desired directions by getting the infant to reach for brightly colored objects, interesting toys, etc —a primitive type of muscle re education When considerable muscle power has apparently been regained, the splint is gradually and progressively omitted during waking hours, but kept applied at night and during sleep at other times The passive but gentle forcing of the motions described above and the massage should be continued, but more and more attention should be devoted toward eliciting active motion and function use of every sort from the child

Under this regime, in favorable cases, steady improvement may be noted, resulting eventually in a degree of recovery

which, while practically never complete, may give a serviceable extremity, although always with a growth disturbance resulting in a generally smaller extremity The night wearing of the brace has to be maintained for six months to a year or more, depending on the severity of the lesion and the tendency to the formation of contractures

It is obvious that the success of conservative therapy in these cases hinges on the early institution of treatment, and on meticulous and constant care in the early months The cooperation of the family and intelligent medical supervision are equally important The progressive stages of therapy must be properly paced Patience and ingenuity are often more effective than vigor and enthusiasm The cooperation of the family and the intelligent medical supervision should continue long beyond the apparent attainment of a satisfactory result, since cessation of effort may be followed by loss of the apparent gain, and the development of late contractures

Conservative Therapy — Lower-arm Type The prognosis here, as has been stated, is poor The conservative therapy follows the same general pattern The splinting maintains a slightly flexed wrist and fingers with moderately abducted and flexed thumb Stretching and massage to prevent contractures is carried out for the hand and wrist It resolves itself largely into the problem of trying to maintain passive mobility in the wrist, hand, and fingers, and trying to prevent contractures Ultimately the problem is one of dealing with the disabilities of a hand badly compromised as by poliomyelitis by operative means [See Chapter 7 —Ed]

3 Contractures (Including Resultant Posterior Subluxation at the Shoulder Joint) Contractures may develop despite conservative efforts to prevent them, or may be seen fully developed in late cases With contracture there develops progressively a marked internal rotation at the shoulder with shortening in the subscapularis and the pectoralis major, which may be intensified by contracture in the fore arm pronators Less commonly flexor contraction at the wrist may also ensue With the shoulder element, in time, there may be associated a posterior displacement of the humeral head In some of the older cases this is also accompanied by a downward angulation of the acromion process, and an increase in the length of the coracoid process

When contractures tend to develop during the course of, and despite, adequate conservative treatment as described above, manipulation under anesthesia, even repeatedly if necessary, may be added to the conservative therapy, and may control the situation In cases seen up to one year of age with contractures already developed, manipulations under anesthesia should be resorted to followed by, and combined with, the conservative therapy After one year of age, and up to the end of the second year, the chance of success of manipulative procedures is definitely diminished but they may help to limit the degree of contracture which develops After the end of the second year, manipulative procedures are hardly worthwhile, but may be attempted

It is, of course, essential that all manipulations in these young children be carried out with great circumspection and caution, as severe damage can be done by relatively little force injudiciously used It is also wise to remember that a manipulation which inflicts considerable trauma may do far more harm than good Several manipulations of less severity may be of greater benefit and entail less risk, despite the repeated anesthesias

In the cases which have developed contractures during conservative treatment, or which have been seen after their development, and in which manipulation and conservative treatment have not been successful, physical therapy and protective splinting should be maintained until the end of the fourth year Surgical correction for the

upper arm residua can be resorted to after the lapse of that time

The surgical procedures available, and their indications, are as follows

THE SEVER OPERATION (Fig 260) This operation is optimum for those cases showing marked limitation of abduction and external rotation, without posterior subluxation of the humerus, and without any marked secondary torsional deformity in the upper humerus It alone is not considered adequate for the cases with posterior luxation or for those with marked torsional bony deformity, and the improvement in function gained by it is not enough in the cases of mild restriction of motion to make it worthwhile

PROCEDURE The skin incision is made directly downward from the tip of the acromion to the anterior border of the deltoid below the lower border of the pectoralis major insertion It is well to ligate and cut the cephalic vein high and low The pectoral insertion is exposed, cut close to the humerus, and the muscle is separated and retracted mesially With the arm held in as much external rotation and abduction as possible, the elongated coracoid can be located by following up the exposed coracobrachialis muscle The end of the coracoid is cut across, freeing thereby the attachments of the coracobrachialis, the short head of the biceps and the pectoralis minor, which attach to the coracoid tip and allowing immediate marked increased in abduction and external rotation The coracoid tip and the attachments to it are retracted downward and mesially The deltoid is now retracted outward, and the capsule and musculotendinous cuff of insertions into the tuberosities revealed The edge of subscapularis is defined, and by blunt dissection the insertion of its tendon into the lesser tuberosity mesial to the biceps groove is defined A sound is passed under the tendon close to its attachment from below upward, and between it and the underlying capsule The subscapularis tendon is completely divided close to the tuberosity, and the arm carried into full abduction and external rotation After suture of the wound the arm and shoulder are placed in an abduction external rotation plaster spica It is kept there for two to three weeks in the same position as advised for conservative therapy and described above At the end of that time the

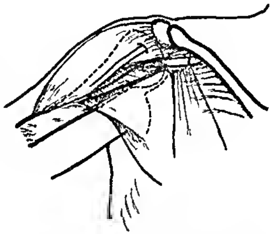

Fig 260 The Sever operation Incision is deepened in interval between deltoid and pectoralis major Insertion of pectoralis major is cut at the bone and the muscle retracted down and in Retraction of deltoid outward allows exposure of coracobrachialis and short head of biceps up to elongated coracoid from which pectoralis minor runs downward and inward Section of coracoid allows retraction downward of these muscles with attached coracoid In abduction and external rotation subscapularis tendon can then be defined and cut as described in text, allowing full abduction and external rotation

plaster is removed and a brace maintaining the same position is applied The brace is removed daily or several times daily for physical therapy and gradually increasing aided active exercise The brace is worn until voluntary active exercise is satisfactory

In the very severe and long standing cases abduction to the full at the close of this procedure may not be possible because

of contracture in the latissimus dorsi and the teres major Steindler has added to the operation the section of these insertions through a separate incision along the posterior axillary fold This may weaken the power of the extremity somewhat

Rotation Osteotomy for Internal Rotation Deformity The indication for this operation is the correction of deformity It does little to improve function in the contracted cases and is not applicable to cases with subluxation or marked torsional deformity The skin incision is the same as that for the Sever operation The interval between pectoralis major and deltoid is developed to expose the humerus The arm is carried into abduction and a transverse osteotomy of the humerus is done the biceps tendon being protected The shaft fragment is then rotated outward 90° on the proximal fragment The wound is closed and a plaster spica is applied similar to that described under the Sever operation above This is worn for eight weeks following which gradual resumption of active function is encouraged The names of Lange abroad and Mark Rogers in this country are associated with this operation

Operation for Posterior Subluxation or Torsion of the Humerus Putti s Operation (described by Scaglietti of the Instituto Rizzoli) This was devised for cases having both contracture and posterior subluxation with torsion A Sever operation is carried out as the first stage including osteotomy of the down bent acromion if it interferes with reduction of the humeral head (The Sever operation if done in the presence of a subluxation employs section of the acromion if necessary to reduce the dislocation) The initial plaster spica is applied as described under the Sever procedure but is kept on for from six to eight weeks When it is removed and to prevent the recurrence which is apt to take place after this operation when done in the presence of subluxation and torsion the lower half of the incision is opened and a transverse osteotomy is done through the humeral neck while the arm is held so that the humeral head lies in the glenoid The head is maintained in its reduced position while the shaft and arm are rotated outward until the shaft occupies a normal position in relation to the reduced head A new plaster spica is applied and is worn for about eight weeks following which gradual resumption of active function is encouraged

There are other operations but these three embody all the advantages to be obtained In coming to a decision as to whether or not to use them one must carefully evaluate the indications and what can be expected from them As can be appreciated from what has already been said without adequate power for a reasonable amount of function none of them are of value The mere rotation osteotomy has some aesthetic value The others are for the purpose of relieving contractures and reducing and maintaining reduced posterior dislocations with or without torsion, provided functional activity can be exercised afterward The cases which recover reasonably well under conservative treatment usually do not require them, and the very badly compromised cases cannot benefit much by them The field for their use is therefore limited

Operations for Pronation Contracture and Wrist flexion Contracture The procedures associated with the names of Tubby and Mayer are described in Chapter 7 These operations can be combined with one for wrist flexion deformity by dividing the tendon of the flexor carpi radialis at its insertion and inserting it into the opened sheath of the extensor carpi radialis longus suturing it to the contained tendon within the sheath This is done through an incision along the lateral aspect of the lower radius and the proximal carpus

4 Residual Palsies In the upper arm type and in the whole-arm type in which conservative treatment has resulted in im

provement to a point where they have become essentially upper arm type, residual weakness in the extensors of the wrist and the long finger extensors may be compensated for by the operative procedures described for poliomyelitis affecting the same group in Chapter 7 In the lower arm type because of extensive involvement of the intrinsic muscles of the hand the problem is a great deal more complex, but the procedures described in Chapter 7 may be of help in giving some semblance of use to the hand except in the extreme cases

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SECTION THREE

AFFECTIONS OF BACK, MUSCLES, FASCIAE, TENDONS, BURSAE, AND GANGLIA

9

Low-back Pain

JOSEPH A FREIBERG, M D

INTRODUCTION

Great strides have been made in the past decade toward a clearer understanding of low back pain The rôle of the sacro-iliac joints has assumed smaller proportions while the lumbosacral joint as well as the protruded intervertebral disk and hypertrophied ligamentum flavum have increased in importance as etiologic factors Too great responsibilities, perhaps, are now invested in the protruded intervertebral disk The recognition and operative removal of the offending disk fragments has cured many people of their backaches and sciatica—but is surgery always necessary? Also, in the past decade, a clearer conception of the rôle of muscular and fascial structures in connection with low back pain and sciatica has been reached With these latter advances have come new operative procedures that have proved most beneficial in properly selected cases

The foregoing notwithstanding, conservative, nonoperative therapy for low back pain still relieves and cures more than two thirds of the cases These conservative means consist in the application of time tried and proved procedures—postural correction, traction, manipulation, physical therapy, and immobilization by plaster or braces

Differentiation must be made between active infectious lesions of the soft tissues and osseous structures, and purely mechanical lesions, though the latter may be the result of a preceding infectious or inflammatory lesion Obviously, ill-chosen surgical procedures in the presence of inflammatory or arthritic processes may have dire results

In the low back there are three sites where motion occurs in the sacro-iliac joints, in the zygapophyses or true joints between the articular processes and between the vertebral bodies around the inter vertebral disks Injury or disease in any of these loci is associated with muscle spasm as elsewhere in the skeletal system Though a joint lesion may be the primary source of trouble, the secondary muscle spasm may be the actual cause of pain and disability In the occasional case, therapeutic measures directed at the secondary or soft tissue lesion may entirely relieve the patient, but such a plan of therapy must be used knowingly This must be borne in mind constantly, as dissimilar primary lesions may be, and are, associated with similar types of muscle spasm responses The clinical picture of the so-called sciatic scoliosis, with limitation of motion of the low back and restriction of motion in the straight leg raising test, is not diagnostic of any one lesion Trauma, arthritis, fasciitis, or structural instability due to osseous anomalies may cause similar clinical pictures in the low back By careful study and analysis alone may the true diagnosis be made, and only then can the therapy be planned

The primary lesion associated with low-

back pain may be a true joint lesion synovitis, a ligamentous trauma periostitis at the site of muscle origin or insertion, myositis fasciitis or a lesion in the neural canal, such as a protruded disk a hypertrophied ligamentum flavum or a caudal tumor The etiologic factor initiating the syndrome of back pain with or without sciatica, may be a trauma disrupting the normal function of a joint a ligamentous or periosteal tear associated with primary localized hemorrhage and secondary fibrosis or scar tissue formation It may be a gradual fascial or muscular contracture dependent primarily on faulty posture In this last instance the faulty posture may be due to an osseous anomaly associated either with hypermobility and instability of the lumbosacral or fourth and fifth lumbar articulations or muscle imbalance dependent on some other cause, such as pregnancy with persisting relaxation of the abdominal muscles The primary lesion in many cases is similar to lesions occurring commonly about other joints of the body but obscured because of the intricate mechanism involved in the lower part of the back Furthermore this joint or ligamentous lesion initiates a series of muscle re ponses which may be common to all of the different primary lesions

Obviously before an attempt is made to treat a syndrome involving low back pain the lesion must be identified The history of the mode of onset is especially important as this sign often indicates a ligamentous or periosteal tear which may well be the lesion to be treated Postural strains, such as accompany automobile driving and faulty position at a desk, frequently initiate a muscle imbalance causing an anomalous lumbosacral structure to become symptom producing Equally important in the history is the fact that certain body positions or attitudes relieve the pain Finally, the detailed history in the case of both acute and chronic backaches is just as important as in other bodily ailments

On physical examination the signs and symptoms associated with low backache may be numerous or few, depending on the individual case The acute low back pain with or without sciatic pain should be approached in a manner entirely different from that suited to the chronic case Many of the acute cases of recent onset represent ligamentous periosteal, or muscular tears with associated local bleeding An extensive physical examination accompanied by forceful testing of the range of mobility of the various joints is definitely contraindicated as it is in the case of acute ankle or knee lesions Manipulation under these circumstances will tend to aggravate the lesion and increase the degree of damage, although an existing painful muscle spasm may be temporarily relieved Observation and palpation will elicit the location of the areas of tenderness and injury Acute ligamentous, capsular, and muscular lesions elsewhere in the body are treated by immobilization and the control of local bleeding Therefore in similar lesions about the lower back region immobilization by adhesive strapping and bed rest accompanied by cold compresses or ice bags is similarly indicated for at least 48 hours These soft tissue lesions require from seven to 21 days to heal therefore supportive therapy should be pursued for this period It is the failure to recognize the nature of these initial lesions which contributes toward many of the recurrences of symptoms and

toward many of the secondary persisting ligamentous, fascial and muscular lesions seen in the chronic cases of low back pain Ligamentous tears healed by relatively wide bridges of cicatricial tissue result in elongated or contractured ligaments with a relative loss of elasticity Untreated periosteal tears are followed by areas of organized subperiosteal hematomas and fibrous tissue infiltration Similar sequelae develop in muscle lesions The sites of these soft tissue lesions about the lower part of the back are fairly constant, as determined by areas of pain or more reliably, by point tenderness on pressure

The more severe low back injuries may be accompanied by lesser fractures involving articular processes, laminae, or pedicles. The prompt recognition of a fracture involving the arcus of a vertebra and its subsequent immobilization will prevent many chronic complaints involving the lower part of the back These fractures, although often isolated and small, are true fractures not only capable of producing symptoms but requiring from eight to ten weeks to heal Ununited, these lesions may offer sufficient local instability to be the basis of recurrent or constant pain

The exact mechanism and degree of trauma preceding ruptures of the annulus fibrosus and consequent posterior protrusions of the intervertebral disks has not been definitely determined Likewise, the less frequent lesions of the ligamentum flavum followed by hypertrophy or cicatricial thickening of the ligament are not clearly understood That these lesions do occur, and that they may be associated independently with constant or recurring attacks of low back pain with or without sciatic pain, must be accepted However, that these lesions occur and that in many cases, reported by many authors, complete recovery has followed laminectomy does not indicate that in all instances recovery or relief from symptoms depends solely on removal of the lesions The functional mechanism of the lower part of the back is intricate, and varies extensively with the functional demands placed on it hence it is highly probable that more than one factor is responsible for the production of pain or dysfunction in many cases

Likewise, the elimination of one of two or more abnormal conditions in a given case may result in complete relief from symptoms and clinical recovery From the very nature of the lesions found at operation and the frequent absence of history of recent injury, a protruded disk and a recent low back pain cannot always be correlated Previous episodes of low back pain in a patient may have been relieved by conservative therapy, but in a later, possibly more severe attack a protruded disk has been discovered and removed Was this disk the causative factor in the previous similar attack of back pain? An analogous situation may arise in the case of congenital isthmus defects of the fifth lumbar vertebra (Fig 34) entirely symptomless for 25 or more years, which are discovered associated with an attack of low back pain with or without sciatic pain The instability of the lumbosacral joint in this instance may be, and often is, a predisposing factor in the clinical picture nevertheless a certain number of these patients are cured or relieved by nonoperative therapy, or by lesser operative procedures not actually involving the isthmus defects

The history of momentary acute increase of pain in the low back, buttock, or sciatic nerve area accompanying sneezing or coughing is frequently considered a diagnostic sign of a cord tumor, protruded disk, or hypertrophied ligamentum flavum—the aggravation attributed to a transient increased intraspinal fluid pressure On the other hand sneezing and coughing are closely linked with spasmodic contracture of the abdominal and back muscles Lesions of the fasciae, muscles, or joints may, therefore, be equally affected momentarily Especially is this true of periosteal lesions

So-called sciatic scoliosis, with flattening

or convexity of the lumbar spine may accompany any acute or subacute lesion of the lower part of the back and in itself is indicative of only an irritative lesion of the neuromuscular mechanism of this region

Relief from pain and disappearance of muscle spasm on lying down generally imply that a postural or abnormal mechanical strain has been removed from a lumbosacral or sacro iliac joint Intraspinal lesions—protruded disks and hypertrophied ligamenta flava—usually although not constantly are unaffected by changing of position such as lying down or sitting

In the presence of muscle spasm or contracture of the gluteus maximus or hamstring muscles or both limitation of forward bending in the standing position as compared with the sitting position has relatively little significance as in standing the affected muscles are put on increased tension and in sitting they are relieved of this tension In the absence of muscle spasm or contracture of these muscles however this test aids considerably in differentiating between lumbar and sacro-iliac or fascial lesions

Limitation of passive lumbar flexion in the supine position signifies a lumbar or lumbosacral articular lesion

The straight leg raising or Lasegue test when definitely positive may be interpreted in several ways Such limitation of hip flexion with the knee extended may be due to spasm of the gluteus maximus and hamstring muscles caused by lesions of these muscles or their periosteal origins lesions of the sciatic nerve or its nerve roots or articular lesions of the sacro iliac or lumbosacral joints accompanied by muscle spasm On the other hand pain induced on one side only regardless of which leg is tested should center attention on the lumbosacral or the sacro-iliac joint of the painful side

The Ober[1] test for contractured thigh fascia may be positive as the result of muscle spasm involving the tensor fasciae femoris and gluteal muscles When this test causes a localized pain a periosteal lesion should be suspected When the Ober test is positive during an interim between attacks of back pain it is really indicative of contracture of the fascia lata or of the iliotibial band

The Ely* or prone knee flexion test is one of the most valuable maneuvers to demonstrate the existence of thigh fascial contractures but not of a lumbosacral lesion as originally described Because of the position of the patient spasms of the glutei and hamstring muscles play practically no role If on passive flexion of the lower leg on the thigh in the prone position the buttocks arch away from the table and at the same time the leg abducts at the hip joint a true contracture of the anterior and lateral thigh fascia is demonstrated

In the supine position with the knee extended internal rotation of the leg followed by slight flexion of the hip and adduction of the leg may cause localized pain in the buttock (author s maneuver) When associated with pain on pressure over the pyriformis muscle one of two lesions is indicated—either a lesion of the pyriformis muscle or a lesion of the sciatic nerve or its sheath in the region of the pyriformis muscle

Again in the supine position on passive twisting or rotation of the pelvis by forcing the flexed hip and knee of one side across the body while fixing the ipsilateral shoulder limitation of motion on one side associated with pain suggests an articular or capsular lesion of the lumbosacral or sacro-iliac joint depending on the site of the pain

Probably the most valuable of all the tests in determining the exact site of periosteal ligamentous or joint lesions is the localization of one or more areas of definite tenderness on palpation when the patient is lying comfortably on a firm table Unless a careful routine is carried out the area of maximum tenderness may be missed upon examination

The details of a complete neurologic examination have no place in this discussion

but, obviously, in many instances of persisting or chronic low back pain such an examination is required A diminished or absent Achilles tendon reflex does not always signify the existence of a protruded intervertebral disk, but this is often the case Subjective numbness or the sensation of coldness of the leg in the absence of objective sensory changes does not indicate an essential sciatic nerve lesion A neurologic examination will exclude central nervous system degenerative lesions or peripheral neuritis When the general observations suggest an intraspinal lesion lumbar puncture studies and, if indicated, visualization studies with iodized oil should be made

A correlation of the clinical, neurologic, and x ray findings must be made without prejudice *An anomalous osseous lesion, or a neurologic sign which does not fit into the clinical picture, must be considered a coincidental finding*

In concluding this discussion of low back pain and before describing specific methods of treatment, one fact must be borne in mind There is no absolute uniformity of opinion regarding the causes of all the types of low back pain On the premise that low back pain, with its numerous manifestations, on hypothetical and on proven bases may be due to many varied mechanical and infectious lesions, various types of therapy have been popularized in America, in England, and on the Continent For this reason there is a great divergence of opinion, among experienced orthopedic surgeons, regarding the extent to which supportive, or manipulative, or surgical procedures should be used It must be assumed that the therapeutic indications will differ depending upon the diagnosis That cures are obtained by various types of treatment, in apparently similar cases, emphasizes the need for careful study of each case before instituting therapy The contraindications for any one type of manipulative or surgical procedure must be weighed equally with the indications for such a procedure

[This excellent discussion of pathologic states signs and symptoms is included here because of its direct bearing on the formulation of any intelligent plan of treatment for the so called low back case —Ed]

DIAGNOSTIC SURGICAL PROCEDURES

Physical Examination

The presence of fixed or apparent deformities should be carefully noted Any limitation of motion in any direction of the lower spine or hip joints should be recorded and evaluated according to the body type of the individual under consideration and the age of the individual By the usual methods of examination in different positions contractures of the soft tissues including the fasciae, must be differentiated from limitation of joint motion With the patient in the prone position, palpation of all of the bony prominences the sites of ligamentous and tendinous origins and insertions and the site of true articulations should be examined by both gentle and deep palpation All areas of tenderness as well as areas that produce pain elsewhere by localized pressure must be noted A complete x ray examination must include exposures made in different planes and preferably stereoscopically

Procaine hydrochloride Injections (Steindler[3])

The injection of 2 to 5 cc of 1 per cent procaine hydrochloride solution into one or more sites of tenderness may *temporarily* relieve not only the local back pain but, likewise, an associated leg pain When relief follows the injection of the procaine hydrochloride, the exact site of the fascial, ligamentous, or osseous lesion has been found and the therapy, conservative or surgical, may then be outlined (Fig *261*)

Whereas the injection of novocaine or procaine hydrochloride solution into the site of tenderness not infrequently is followed by more than a temporary relief from pain,

several authors have advocated the use of injection methods consisting of anywhere from 25 to 50 cc of fluid as a curative type procedure The success of this type of cura

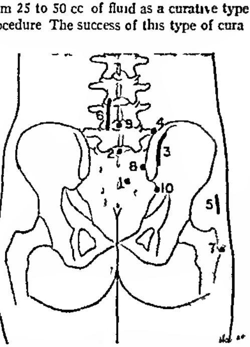

Fig 261 Trigger points of Steindler Areas shown represent sites of tenderness which may be associated with back and leg pain due to muscle tendon, or ligament injuries causing reflex or referred pains Injection of 1 per cent novocaine into one or more existing tender areas accompanied by relief from symptoms indicates a soft tissue lesion amenable to supportive or fascial surgery

(1) Sacrospinalis syndrome (Steindler), (2) lumbosacral syndrome (Steindler) (3) gluteal syndrome (Steindler), (4) transversosacral syndrome (Steindler), (5) tensor fasciae latae syndrome (Steindler) (6) myofascial syndrome (Steindler) (7) trochanteric bursa (8) posterior ligaments and capsule of sacro iliac joint (9) capsule of zygapophysis and (10) sacro iliac joint

tive procedure has varied considerably in the hands of different men As the injection of a fluid into tissues can only stretch them or alter the circulation in them it must be assumed that if this procedure is curative correction has been accomplished in one of two ways—namely, (1) a reflex arc has been interrupted and muscle spasm has been relieved, the initial cause having disappeared in the interim (2) subperiosteal fascial, or intramuscular adhesions following an inflammatory or traumatic lesion have been stretched by the injection procedure

Spinal fluid Studies

Spinal Puncture For low back pain a small caliber spinal puncture needle is introduced in the usual manner, preferably at the fourth lumbar interspace Before with drawing any fluid careful manometric studies are made to determine the presence or absence of interference with the normal dynamics of the cerebrospinal canal The more accurate manometric studies are made when a blood pressure cuff is placed about the neck, and in place of the ordinary methods of compression of the jugular vein the cuff is inflated and the rise in manometer is noted, or the absence of rise is equally noted, and the pressure is quickly released from the blood pressure cuff

Though actually offering no great difference from digital jugular compression, the blood pressure cuff method has the advantage that a constant pressure may be exerted on each patient The failure of the fluid to rise in the manometer on the application of jugular compression is a positive Queckenstedt test, signifying an obstruction in the normal flow of the cerebrospinal fluid somewhere between the fourth interspace, or site of the spinal puncture needle and the cervical spine Furthermore, if the fluid in the manometer rises rather slowly and subsequently drops rather slowly on the release of the cervical pressure, an incomplete obstruction to the spinal fluid may be suspected Sufficient fluid is slowly withdrawn into several test tubes approximately 2 5 to 3 cc per tube Protein determination is made on the first tube Assuming that the protein content of the spinal fluid will be higher at the site of the lesion, a low back intraspinal lesion is suspected if the protein in this tube is high Protein content of more

than 40 mg per 100 cc of fluid is considered a significant elevation [Many men regard readings of less than 50 of doubtful significance —Ed] On the second and third tubes of spinal fluid cytologic and serologic studies are made An increase in cells or positive serologic findings obviously indicate further studies

Spinograms or Air Myelography This method of localization of extradural and intradural lesions in the lower spinal canal has an advantage over injection of opaque oil inasmuch as the air injected is eventually absorbed On the other hand this method of examination has not proved universally satisfactory, and in the hands of many is still considered somewhat unreliable When the procedure is carried out meticulously and the findings are definite, however, it has proven to be a most satisfactory procedure If the Queckenstedt test has been positive the patient sits upright on the table bending forward and 4 to 6 cc of air are injected below the level of the suspected lesion and immediate anteroposterior stereoscopic and lateral x ray films are made If, however there is no suspected block the entire lumbocaudal subarachnoid sac must be visualized Chamberlain[4] says

> This is done by placing the patient on the side with the table in Trendelenburg position at an angle of from 30 to 35° An 18 or 20 gauge needle is inserted into the subarachnoid space at the second lumbar interspace and spinal fluid is exchanged for air in 5 cc volumes until air returns from the needle It usually takes from 30 to 50 cc of air to fill the canal in adults, depending upon their size The needle is then withdrawn and the patient moved onto an ordinary horizontal x ray table equipped with a Bucky Potter diaphragm, the table being elevated at one end by blocks in order to maintain the Trendelenburg position It is important to keep the patient's head lower than the rest of the body or the air will ascend into the cranium In such an event, the resultant loss of air content from the spinal canal may interfere with the success of the myelographic procedure, and the patient invariably suffers more or less from headaches when this happens Stereoscopic lateral and anteroposterior projections with the patient in the usual conventional positions except for the Trendelenburg position are sufficient in most instances Additional lateral x rays with the lumbar spine held in hyperflexion and hyperextension give additional information in some instances

A careful examination of the x ray films made following the injection of air will demonstrate the presence of a filling defect due to an extradural lesion and an obstruction of the subarachnoid space or filling of the caudal canal by a neoplasm or an inflammatory lesion of the meninges Considerable experience is required however in the accurate and satisfactory interpretation of the x ray films made following air myelographic studies The positive findings are of greater significance than negative findings with this method of examination of the subarachnoid space

Injection of Opaque Contrast Medium Lipiodal Lipiodal injection into the subarachnoid space is resorted to in the following conditions (1) If the protein content of the spinal fluid is found to be elevated above 40 mg per 100 cc , (2) if in spite of normal spinal fluid findings there is still the impression that there is an intradural or extradural lesion in the neural canal (3) if the result of the spinogram or air myelography is inconclusive or (4) if there is lack of confidence in this latter procedure, as is often the case As lipiodal is heavier than the spinal fluid, the patient is kept in the recumbent position at the time of examination With the patient lying on his side on a tilting fluoroscopic table, preferably equipped to take spot x ray films, 5 cc of the lipiodal (heavy) are injected at the fourth lumbar interspace As 5 cc of lipiodal do not fill the lumbocaudal sac, the displacement of the spinal fluid by the lipiodal must be controlled by the position of the patient Under the fluoroscope, with the patient in the various possible positions including prone, supine and lying on each side, the head and feet are respectively ele

vated and lowered The flow of the lipiodal from one level to the other can be controlled by the angle of the patient and can be satisfactorily observed on the fluoroscopic screen When a constriction in the lipiodal shadow mass or an apparent obstruction around which the lipiodal flows is noted spot x ray films are made for later study As with the use of the fluoroscopic screen the field of vision is often cut down for accuracy it is of great help if small lead markers are attached to the skin of the patient with adhesive so that the exact level under examination can be determined from a known vertebral level

In a great number of cases 2 cc of lipiodal are sufficient for localization of lesions in the lower lumbar canal On the other hand there are many with wide experience (Camp[3]) who feel that the use of 5 cc. results in a more satisfactory examination and does not increase the reaction Although there is adequate evidence that under ordinary conditions the injection of lipiodal into the subarachnoid space causes no permanent changes it is generally considered unwise to inject lipiodal unless the probabilities are that an operation is to be resorted to at which time the lipiodal may be released from the subarachnoid space The injection of lipiodal is definitely contraindicated in the presence of inflammatory or suspected inflammatory lesions

[It can safely be said that lipiodal is being used less and less as a diagnostic procedure Its accuracy as a diagnostic procedure has not lived up to earlier promise and its innocuousness has been seriously questioned —Ed]

Epidural or Caudal Injections In some instances when the preceding spinograms or lipiodal injections are inconclusive or considered inadvisable and in the presence of positive findings from the original spinal puncture the injection of 50 cc of normal saline solution following preliminary injection of 5 to 10 cc of 1 per cent procaine hydrochloride into the sacral hiatus may increase the symptoms previously noted of low back pain and leg pain When this test is positive it is most suggestive that there is either an intradural or an extradural lesion in close proximity to a nerve root at its exodus from the spinal canal This procedure is sometimes called a reverse Queckenstedt test though incorrectly The occurrence of pain following the epidural injections of the solution is nevertheless a valuable test On the other hand epidural injection of 50 to 100 cc of saline solution relieves a small number of cases hypothetically by freeing adhesions about the nerve roots

Sciatic Nerve Sheath Injection Just below the transverse buttock crease the inferior margin of the gluteus maximus muscle the sciatic nerve may be rather easily contacted with an injection needle A few cubic centimeters of 1 per cent procaine hydrochloride solution is injected into the skin and subcutaneous tissues at this site A two and one half or three inch 20-gauge needle is now inserted in a vertical plane and the sciatic nerve is identified by the subjective complaints of local and lower leg pain After injecting a few more cubic centimeters of procaine hydrochloride solution into the nerve sheath 50 cc of physiologic saline solution are injected rather rapidly to distend the nerve sheath In selected cases with nerve-trunk tenderness satisfactory relief from symptoms follows

MECHANICAL OR SUPPORTIVE THERAPY

Under this heading is included the majority of the so-called conservative or nonoperative procedures used in the management of low back pain Some of the following procedures in certain circumstances are used as diagnostic tests—namely the use of traction—whereas under ordinary circumstances the various procedures to be described are resorted to following careful examination of the patient and a definite conclusion as to the etiologic factors involved in the backache

PHYSIOTHERAPY

The choice and use of the various modalities available under the care of a trained and qualified physiotherapist is a subject too broad to be discussed here Essentially, the use of physiotherapy in the treatment and cure of low back pain consists in the use of physical means by one especially trained Following an injury or acute back sprain cold compresses or ice bags should be applied for the first 48 hours Immediate application of heat and massage tends to increase the bleeding and congestion of the traumatized tissues Following this 48 hour period, however heat and massage—but not kneading—causes muscle relaxation and stimulates the absorption of extravasated blood For the very painful, acute lesions hospitalization and daily physiotherapy will shorten the period of illness A firm mattress re enforced by fracture boards reduces the tension in injuries of the muscles and fasciae If the lesion be a lumbosacral articular sprain, however, the patient is more comfortable in a mild Fowler position—flattened lumbar spine and knees flexed Unless the recumbent position aids in the relaxation of the patient the heat and massage will accomplish little

Low back pain associated with habitual faulty posture, whether it be of the fatigue type or due to soft tissue contractures after an injury, may be corrected by muscle training under the guidance of the physiotherapist, in combination with an external support (for braces see p 289) In this manner 80 per cent or more of the ordinary backaches are cured Correction of faulty posture can be accomplished with the cooperation of the patient if there be no serious structural abnormality The type of exercises prescribed depends upon the nature of the postural variation For an increased lumbar lordosis emphasis is placed on the abdominal and gluteal muscle exercises If there be an abnormal lumbar flattening or kyphosis, the exercises are confined to the erector spinae muscle group (See any stand ard physiotherapy text) In many instances correction of static deformities of the feet with or without accompanying chronic foot strain, relieves secondary postural abnormalities with low backache As pronated feet may cause an acute or chronic ligamentous knee strain so may they be the basis of an acquired malposture of the spine It is important therefore that in attempting to correct the spinal posture adequate attention be given to the feet Not infrequently, in men especially moderate elevation of the heels will compensate for a contractured calf muscle group and thereby cure a secondary low backache Lowering of the heels in women's shoes will often relieve the low back pain due to the secondary lordosis or increased lumbosacral angle—a compensatory postural deformity from the wearing of high heels On the other hand judgment must be used in determining the exact heel height and over correction in heel changes must also be avoided

IMMOBILIZATION

Traction In the presence of muscle spasm or muscle contractures associated with low back pain the judicious use of skin traction has no substitute As the purpose of the traction is to overcome the effect of muscle spasm and thereby rest an inflamed or irritated low back joint a heavy pull is not indicated Russell traction or modified Russell traction is the most easily applied [For Russell traction, see Chapter 22 —Ed] The patient is placed on a firm bed preferably with fracture boards under the mattress Adhesive strips are applied to the lower leg and with a spreader and a foot-drop support a rope is passed over a pulley attached to the foot of the bed Traction in a straight line usually aggravates the back pain For this reason a cloth or towel sling is passed around the calf of the leg just below the knee, and attached to the overhead bar of a Balkan frame As

the purpose of the sling is only twofold—to maintain a moderate flexion of the hip and knee, and to overcome the friction of the leg lying on the bed—the sling need not be counterbalanced with weights (Fig 262) (A. H Freiberg[6]) When the most comfortable angle of the knee and hip has been determined, seven to ten pounds of weight are attached to the rope from the foot spreader in this line of pull Ordinarily, the foot of the bed is raised on shock blocks, and a wooden box is placed in the bed below the other leg so that the patient may prevent himself from being pulled down in the bed A period of from seven to ten days usually will accomplish the maximum effect to be attained by traction Muscle spasm or contracture not overcome in this period of time requires other means of correction

Adhesive Strapping The purpose of adhesive strapping is to immobilize externally a painful joint and its related musculature At best adhesive fixation of the lower back is inefficient and, therefore, the fixation by this means must include areas well above and below the painful areas In the various special methods of adhesive application several principles are followed The patient must be in a comfortable position before the adhesive is applied, usually lying on a firm table with a small pillow beneath the abdomen The adhesive tape, in two or three-inch widths is applied from a line just anterior to the midaxillary line across the back to the opposite side The strapping should extend from a line transversely just above the trochanters of the femora upward to one or two inches below the inferior margin of the scapulae Ordinarily, if the adhesive be applied obliquely, in layers it is more efficient as in this method of application the gluteal masses are supported (Figs 263 and 264)

In the presence of gluteus medius or tensor fasciae femoris muscle spasm, if the affected leg be abducted and slightly flexed and the adhesive be extended down to the lower third of the affected thigh, additional support and comfort result (Ilfeld[7]) (Fig 265)

Adhesive strapping is effective in the acute case, and as a preliminary immobilizing procedure in many chronic cases

Plaster Jackets The indication for immobilization in a plaster jacket is the need for fixation of the lower spine for a prolonged period—two to eight weeks—in a position of comfort and/or correction of malposture The position of the patient at the time of application of the cast varies with the effect to be obtained Following the relief of a pre-existing muscle spasm a normal degree of lumbar lordosis is desired However, if there be evidence of nerve root pressure—due either to a lumbosacral instability or a protruded intervertebral disk —a position of moderate anterior flexion of the lumbar spine is desirable (Williams[8]) (Fig 271) As in adhesive fixation, plaster fixation must include a generous area of the back above and below the lesion In the case of the lumbosacral area, the plaster should extend below the midline of the buttocks and up to the lower margins of the scapulae If lordosis is desired the encasement must be longer over the front of the body, whereas if forward flexion of the lumbar spine is desired it must be longer over the back of the body Needless to say, the plaster should be carefully molded over the bony prominences, both for comfort and for efficacy If complete immobilization of the lumbosacral area is indicated the plaster should be extended down one leg to just above the knee, with the included hip flexed about 10°

Braces In general, metal braces and corsets are used as supplements for the preceding types of therapy or for relatively mild low back lesions Of the very numerous types devised some of which are illustrated below, the effects to be attained may be stated as follows a check to limit extremes of motion in one or more directions a support to maintain corrected postural deformities a support to aid in maintaining an unusual body posture such as lumbar flexion

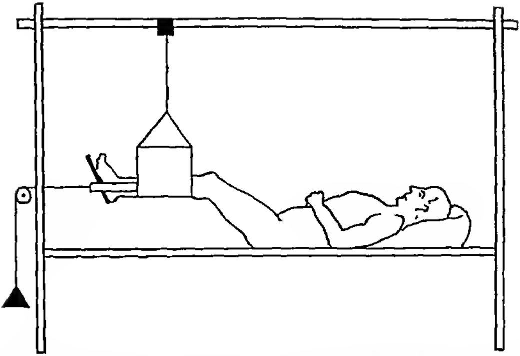

FIG 262 Diagrammatic representation of simple form of traction as used by Dr Albert H Freiberg Sling eliminates friction of bed clothing and maintains proper angle of knee and hip Traction is applied over a single pulley, as shown This method of traction application has many of the advantages of the Russell traction and none of the disadvantages of the old Buck s extension

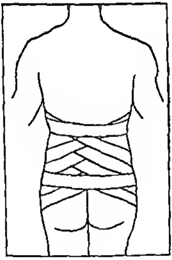

FIG 263

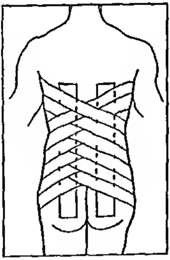

FIG 264

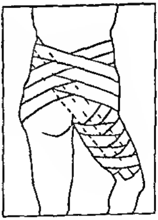

FIG 265

FIG 263 Method of adhesive strapping for lumbosacral and sacro iliac lesions Two- or three-inch width adhesive strips are applied interlacing as shown, and when completed adhesive strapping extends anterior to sagittal plane on both sides and from level of trochanters to and including lower rib margins

FIG 264 Method of strapping for low back pain due to fascitis or myositis which is generalized, or for low back pain associated with generalized degenerative arthritis of spine Two or three inch width adhesive strips are used Diagram is self explanatory

FIG 265 Adhesive strapping for acute low back pain associated with gluteus medius or tensor fasciae femoris muscle spasm—method of Ilfeld [7] Two or more long strips of adhesive are applied to dorsolateral aspect of affected side with leg held in slight flexion and abduction interlacing adhesive is now applied about thigh and low back as shown

with a Williams[8] type support A satisfactory brace, in addition to being mechanically efficient for its purpose must fit closely to the body contours and be comfortable to the wearer The type of brace prescribed must be chosen with consideration given to the mechanical or postural problem involved the body type of the patient, and the occupation of the patient Obviously, in an obese patient, a corset or a steel brace incorporated in a corset is more comfortable than an appliance held only with straps Likewise, for an individual doing strenuous work, a strong metal brace is indicated

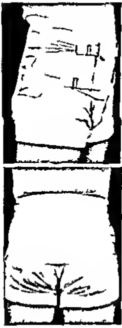

Fig 266 Fig 267

Fig 266 This sacro iliac laced corset gives inadequate support for the true osseous lesions of lumbosacral region For recurrent or convalescent ligamentous or periosteal lesions of low back, however this support is most valuable When recurrent strains are associated with deficient abdominal musculature, this brace is excellent

Fig 267 The Osgood lumbosacral and sacro-iliac brace made of leather with steel reinforcements in the two pads gives adequate support for the relatively mild degenerative and traumatic arthritic lesions in lumbosacral region This brace is especially valuable for those wishing to engage in athletics or moderately strenuous labor Though fitting snugly construction of this brace allows for a moderate amount of movement in low back without causing undue irritation of soft tissues

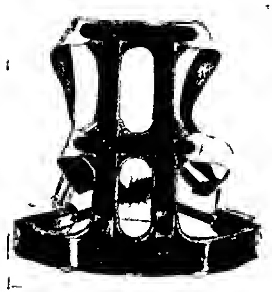

Fig 268 This spring steel low back brace is most useful in low back pain due to degenerative or traumatic arthritis involving primarily, the lumbar spine When well fitted and worn snugly, it acts as an efficient support and as a check rein Brace should extend downward from just below inferior angles of scapulae to just above greater trochanteric level

whereas a simple reinforced corset without elastic material in it will suffice in many other instances Experience has shown that women prefer corsets since they are less visible beneath their clothing than braces, and men prefer the smallest practical support regardless of the material construction (Figs 266 270) In general braces or corsets should be used only as temporary supports during the period when postural deformities, fascial contractures, and weak abdominal or back muscles are being overcome or corrected by supervised exercises

MANIPULATIVE SURGERY

Manipulative surgery has been greatly neglected by the medical profession, with exceptions until recent years Without question there is a definite place for manipulative or stretching procedures in selected cases of low back pain Many traumatic and somewhat strenuous mechanical procedure accompanied by the sensation of sl ht pa or discomfort The various cult ts have ap parently cured many patients who ha e previously failed to respond to le treatment encompassing the use of heat l support It is somewhat difficult to

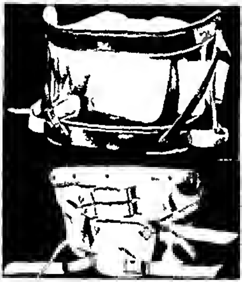

Fig 269

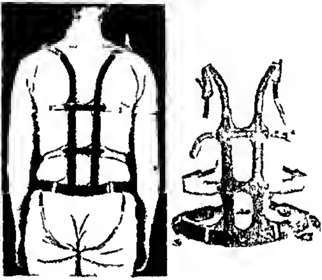

Fig 270

Fig 269 Modified Williams brace as used by author This brace is the most efficient *type support for recurrent low back pain due to arcus defects of fourth or fifth lumbar* vertebrae with or without a mild degree of spondylolisthesis Also used for convalescent protruded intervertebral disk patient, for degenerative intervertebral disk at lumbosacral joint and following laminectomy for a protruded disk in which a fusion operation was not indicated Correctly made and worn, this brace should cause a three-point pressure posteriorly over sacrum below and lower rib margin above, and anteriorly over lower half of the abdomen Upper metal posterior support is pivoted on the uprights so that brace accommodates itself to a certain degree to different body positions, maintaining a firm support at all times

Fig 270 Standard Taylor back brace with peroneal straps may be made of rigid steel or spring steel as illustrated When carefully fitted this support serves excellently for generalized arthritis of lumbar spine or in cases requiring support of lumbodorsal spine This brace is now used less frequently than formerly in cases of low back pain

inflammatory lesions involving the lumbar and pelvic supportive structures are followed by capsular, ligamentous, and fascial adhesions and cicatrix formations The judicious release of these cicatricial lesions is accompanied by return to normal, free mobility, and disappearance of reflex pain sensations And not to be entirely overlooked is the psychologic effect on the patient of a indications for manipulative surgery Obviously, severe osseous anomalies, such as spondylosis or spondylolisthesis as well as destructive lesions and marked arthritis are contraindications In general it may be said that recurring attacks of low back pain not associated with any gross anatomic defect or disease, but accompanied by muscle spasm or soft tissue contractures are the

criteria for manipulative surgery in the hands of the exponents of this type of therapy

The basis for the relief of pain which follows manipulation is the immediate increased mobility after fascial, capsular, and muscular contractures have been overcome If an active infectious lesion is present, the

kin,[15] and others have described special methods of manipulation for low back pain To summarize the principles of the various methods, it may be said that the limitation of motion in the lumbar spine and hip joints in the individual case is either overcome at a single manipulation under anesthesia, or by several treatments without anesthesia

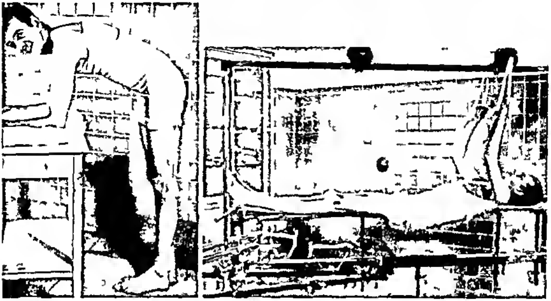

Fig 271 Showing two methods of applying lumbar flexion jackets In recumbent position patient is lying on a canvas sling (Bell fracture table) The lines on the stockinet in the standing position indicate the plaster margin—upper includes lower rib margins lower extends well over buttocks This type of jacket is indicated in the conservative management of protruded intervertebral disks, acquired or congenital zygapophyseal or facet lesions, and osseous encroachment on the foramina of the spinal nerves

relief is only temporary, and the lesion is often aggravated If the real lesion is an unrecognized osseous instability of the lumbosacral joint, the muscle spasm promptly returns with increased severity Obviously, manipulative surgery must be chosen as a therapeutic measure only after the case has been thoroughly studied

Manipulation for low back pain, with and without leg pain, according to different technics, is done as an office procedure, or under anesthesia followed by immobilization in plaster in a hospital Goldthwaite,[9] Baer,[10] Cofield,[11] Mennell,[12] Jostes,[13] Lewin,[14] Pit

Obviously, the surgeon must know what the normal range of motion should be before attempting manipulative procedures Likewise, the variation in mobility in the several body types must be recognized Manipulations are carried out on a firm examining table or on a blanket-covered floor The various movements carried out passively, with variations, are

1 Lumbar flexion with the patient in a supine position—the lumbar spine is flexed by forcing the flexed knees to the chest

2 Extension of the lumbar spine, with the patient prone, is accomplished by lifting

the legs backward, keeping the knees extended

3 Rotation of the lumbosacral and sacroiliac joints may be done in two ways With the patient supine, either flexed knee is forced across the body toward the opposite axilla while the ipsilateral shoulder is held firmly to the table A second method is to place the patient on his side with the knees and hips moderately flexed, and with the surgeon facing the patient's back, force the iliac crest forward while rotating the shoulder girdle backward This manipulation may be reversed to accomplish rotation in the opposite direction The author prefers the second type of manipulation almost to the exclusion of all others With the patient lying in a semiflexed position on his side, less difficulty is encountered in obtaining relaxation Without anesthesia there is little danger of doing harm by manipulation And, finally, this type of manipulation serves as a valuable means of localizing the exact site of pain On many occasions there is an audible dull click during rotation of the side of the pelvis forward, which is followed by a definite feeling of relief on the part of the patient With the more strenuous manipulations under anesthesia, and followed by the application of a plaster spica, the question will always arise whether or not it is the period of rest in plaster which accomplishes the cure rather than the manipulation

4 Rotation of the lumbar spine in flexion (Jostes[13]) may be done by lifting the pelvis of the prone patient, grasping the anterior crests, and then rotating the pelvis first to the right and then to the left

5 Under general anesthesia, to overcome contractures or spasm of the hamstrings and glutei, with the patient supine (Baer,[10] Goldthwaite,[9] Cofield[11]) while an assistant holds the opposite leg on the table the surgeon gradually forces the leg, with the knee extended, upward, using sufficient force so that the heel almost approximates the ear Following this manipulation, with the knee extended and the hip flexed at a right angle, the leg is forced across the body A plaster spica is applied and left on for a period of from ten days to a month This vigorous type of manipulation has been given up by many because it is possible to produce actual trauma—sciatic nerve rupture or spinal fracture Less vigorous manipulation of this type may be done without anesthesia and without danger to the patient

These passive movements are variously carried out—slowly and forcefully, or with rapid sudden movements The latter method in the conscious patient, is most effective if accompanied by an audible click, though it may have no actual therapeutic significance

Manipulations done without anesthesia are more satisfactorily carried out if preceded by heat and relaxing massage to the lumbosacral area These gentler manipulations may be repeated at intervals of several days, gradually increasing the range of motion Following removal of the plaster after a vigorous manipulation, physiotherapy is always indicated, sometimes for a protracted period

Injudicious manipulation is accompanied by fascial, muscle or capsular lacerations localized bleeding, and increased or new symptoms In the presence of low back pain, the author prefers manipulation without anesthesia and, therefore, within pain limits

FASCIAL AND MUSCLE SURGERY

The Ober[16] Operation

With the patient lying on the normal side, and the normal leg slightly flexed at the knee and the hip, the leg is extended in the horizontal line of the trunk If both sides are to be operated on at the same time, a large sandbag is placed beneath the buttocks with the patient lying on his back Either general or procaine infiltration anesthesia may be used [There is an advantage in the use of local anesthesia in these cases In many instances the severance of one or more particular fascial or septal bands will occasion in the patient a sensation of sudden shock

running down the leg with relief of pain, sometimes dramatic in its suddenness The prognosis in these cases is particularly good —Ed] An incision (Fig 272) is made from about one inch below and one inch behind the anterior superior spine extending obliquely backward and downward to an equal distance beyond the greater trochanter The tense fascia lata and tractus ilio- approximated A firm dressing is applied The patient may be allowed up on the third or fourth day, if only one side has been operated on, otherwise, recumbency should be maintained for seven to ten days

[In the milder cases with positive Ober and Ely signs the exercises suggested by Ober may adequately stretch the fasciae without necessity for operation These same

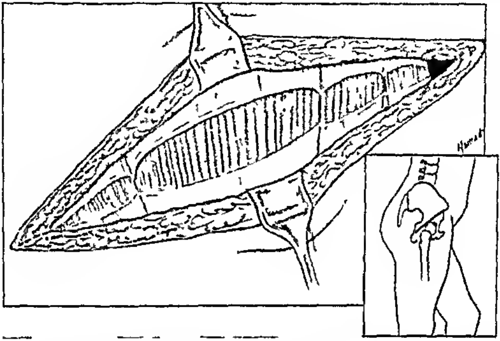

Fig 272 Thigh fascial release operation of Ober Inset shows site of skin incision In this illustration the fascia lata with its intramuscular septa has been cut From left to right muscles which should be exposed are gluteus maximus, gluteus medius, tensor fasciae femoris and sartorius Severance of intramuscular and intermuscular septa is an important part of the operation

tibialis and the fasciae of gluteus maximus, tensor fasciae femoris and sartorius muscles are identified and severed in the line of the skin incision The fascial septi are followed into the intramuscular spaces and severed With the leg adducted or, as described, in the obliquely lateral position, the severed fascial lata and muscular sheaths should now be released from underlying muscle by blunt dissection so that they separate about two inches When hemostasis has been obtained the superficial fascia and skin are exercises have been found to be of definite help in maintaining the initial postoperative improvement

The patient stands 12 to 18 inches from a wall with the involved side facing the wall The hand on the involved side is placed flat against the wall While the feet are kept with soles and heels flat on the floor, the elbow is flexed and the shoulder adducted until the shoulder and, if possible, the hip on the affected side touch the wall This is done slowly and the ultimate posi

tion maintained for a count of ten. This should be carried out 10 to 20 times two or three times a day.—Ed.]

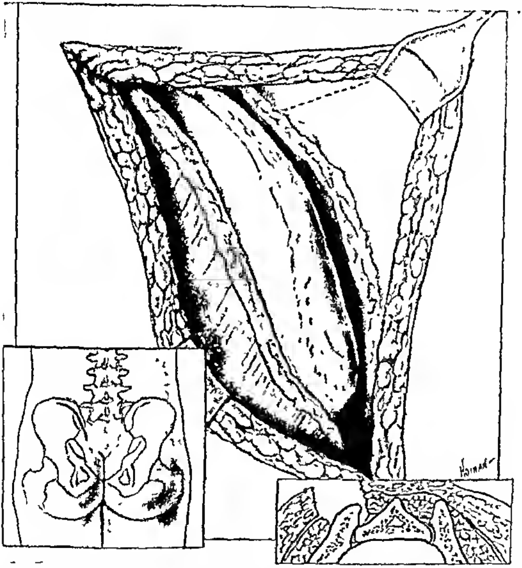

Fig. 273. Iliac muscle release or stripping operation of Heyman Left inset shows line of skin incision Subperiosteally, gluteus maximus and erector spinae muscles are stripped from their attachments to posterior third of iliac crest. If there was tenderness to pressure or apparent contracture of lumbodorsal fascia over sacral area, this is incised along a line as shown in the right upper arm of wound Right inset illustrates extent of muscle stripping in transverse plane.

The Heyman[17] Operation

The patient is placed in the prone position with a pillow or sandbag beneath the lower abdomen. A skin incision (Fig 273) is made along the crest of the posterior third of the iliac crest and down to one inch below the posterior superior iliac spine A single incision or two parallel incisions are now made, one on either side of the iliac crest, through the periosteum. With a periosteal elevator the posterior portion of the

gluteus medius and the entire gluteus maximus origin are subperiosteally separated from the ilium On the mesial aspect of the ilium the erector spinae insertions are freed until on retraction a narrow border of the dorsum of the sacrum is exposed If the dorsal fascia over the erector spinae muscles is contractured, this is severed transversely After hemostasis has been obtained, the wound is closed by suture of the superficial fasciae and skin A firm dressing is applied The patient is allowed up when the soft tissue wound has healed—seven to ten days [This would appear to be an elaboration of and an improvement on the operation of gluteal stripping devised by Percy Roberts for sciatic pain —Ed]

The Pyriformis Tenotomy

The following is the original or first description of the operative procedure as done by the author at the suggestion of Dr Albert H Freiberg A small sandbag or folded sheet is placed under the groin, with the patient prone on the table A skin incision (Fig 274) approximately five inches long is made from one and one half inches lateral to the sacrosciatic notch to within one and

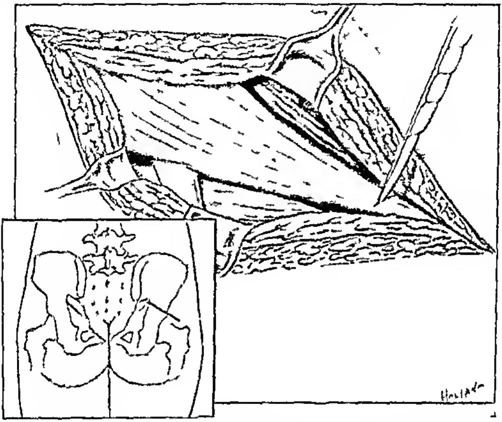

Fig 274 Pyriformis tenotomy—Freiberg Gluteus maximus muscle has been split by blunt dissection and retracted Beneath upper retractor is seen posterior edge of gluteus medius muscle which, at times, overrides pyriformis muscle seen in center of wound Above lower retractor is seen upper margin of superior gemellus muscle Coming out from beneath pyriformis muscle is shown the sciatic nerve—occasionally situated in the middle of a bifid pyriformis or being bipartite and encircling the pyriformis muscle When indicated, tendon of pyriformis is severed as shown Inset shows line of skin incision

one half inches from the superior tip of the greater trochanter In the line of incision the gluteus maximus fascia is incised Running parallel to the skin incision the fibers of the gluteus maximus muscle are separated by blunt dissection If the inferior margin of the gluteus medius is in the line of incision it is retracted upward By further blunt dissection the subgluteal fat and areolar tissue is divided until the conical muscle belly of the pyriformis muscle is identified The pyriformis is readily distinguished from the other rotator muscles as it is situated most superiorly has a thick belly, and also has a relatively long ovoid tendon

The muscle is now gently retracted upward and immediately beneath it is found the sciatic nerve Not infrequently the sciatic nerve has two trunks one extending beneath the muscle and the second through the body of the muscle Very rarely the pyriformis muscle has two tendons half of the nerve emerging between them A thorough exposure of the sciatic nerve is made so that any abnormalities such as adhesions about or thickening of its sheath may be identified The pyriformis muscle is severed at the junction of the muscle fibers and the tendon After retraction of the muscle proper a neurolysis or injection of the sciatic nerve may be done In closing the wound the gluteus maximus fascia the superficial fascia and the skin are approximated in layers An adhesive dressing is applied The patient is allowed up in seven to ten days

Some surgeons have combined the lateral thigh fascia release of Ober with a pyriformis tenotomy by extending the Ober incision posteriorly Through this approach a satisfactory exploration of the sciatic nerve cannot be done Likewise the indications for such a combined operation are not clear This combined procedure is not recommended because of the inadequacy of the approach through the extended Ober incision and because of the lack of any clear-cut indications for its use

OSSEOUS SURGERY

Introduction Choice of Anesthesia

Spinal surgery, including the removal of an autogenous graft is usually done under inhalation anesthesia the type varying with the preference of the surgeon For the longer procedures many have found cyclopropane the most satisfactory In the author's experience infiltration anesthesia with preliminary opiates and barbiturates has been the most satisfactory With this anesthesia there has been less postoperative reaction including shock The routine for infiltration anesthesia must include a barbiturate the evening before and repeated one hour before operation—usually Nembutal one and a half grains The barbiturate prevents procaine reactions as well as lessening the alertness of the patient The anesthesia used is 1 per cent procaine hydrochloride with five drops of adrenalin to the ounce The skin and subcutaneous tissues are infiltrated in the line of incision One cc of the procaine hydrochloride is then injected with a large fine needle subperiosteally over each lamina Unless a nerve root be manipulated as in a laminectomy no further anesthesia is required up to two hours time If a tibial graft is to be taken the procaine is infiltrated in a similar manner including subperiosteal infiltration Unquestionably there is less bleeding due to the adrenalin in the anesthesia mixture and therefore less time is required in obtaining hemostasis Postoperative shock is less frequently encountered Occasionally in removing a tibial graft with a motor saw some pain is experienced as the saw enters the medullary canal of the tibia This pain is brief and rarely severe if desired short supplementary gas anesthesia may be given Infiltration anesthesia works equally well in child or adult if the surgeon has the patient's confidence

Operative Position

The patient is placed prone on the table with the anterior superior spines directly

over the kidney bridge Subsequently, by elevating the kidney bridge or platform the lumbar lordosis may be lessened expediting the operative exposure Also in this position respiratory movements of the abdomen are free To allow adequate chest respiratory movements small sandbags folded sheets or pillows are placed beneath the shoulders Furthermore particularly when using infiltration anesthesia the patient must be in a comfortable position with the head supported on another small pillow

DRAPING OF OPERATIVE AREAS

The spinal site is prepared in the usual manner and after visualizing the line of incision the area is blocked off with sterile towels immediately up to the planned incision An orderly now holds the foot of the leg from which the graft is to be taken up in the air with the knee flexed to about a right angle and the knee raised upward from the table Previously a long sandbag or firm pillow has been placed under the ankles preventing complete extension of the knees—an uncomfortable position especially undesirable if local anesthesia is to be used While the leg is suspended the entire circumference of the lower leg including the knee and extending to the heel is prepared A sterile roll towel now blocks off the upper end of the tibia and a sterile sheet is placed under the leg and the knee is then allowed to rest on the table The surgeon then blocks off the foot and ankle with roll towels or a sterile operative stocking fastened with towel clips or a sterile bandage and the leg is laid on the table Sterile sheets are then applied in such a manner that when the time comes to take the tibial graft on flexing the knee acutely no uncovered areas will be exposed

EXPOSURES

In order to obtain a maximum degree of exposure minimum bleeding and minimum muscle trauma whether the spinous processes and laminae or the iliac crest or tibia is to be the site of surgery, a midline incision carried directly down to the underlying osseous prominences is the best Ligamentous or tendinous attachments to the bone are severed by sharp dissection Then with a broad moderately sharp fishtail type of periosteal elevator the soft tissues are laid back *subperiosteally* en masse from the bone If moderate oozing is encountered a sponge or pack moistened in warm saline is packed in the wound and the other side of the incision is worked on By alternating from side to side in this manner hemostasis is obtained and valuable time is saved Following removal of the sponges if several bleeding areas persist they may be controlled by coagulation or ligatures The use of bone wax is rarely required or indicated On completion of the exposure with retractors in place irrigation of the wound with warm saline solution from an asepto syringe will usually suffice to obtain complete hemostasis As in all bone surgery needless insertion of the gloved hand in the wound should be avoided If digital palpation is required several layers of gauze should be placed over the examining finger However if the exposure is adequate the introduction of the surgeon s hand into the wound is rarely *if ever* necessary

BONE GRAFTS

There are several types of free bone grafts used in low back surgery, each having specific advantages

The osteoperiosteal graft of Delagenière[26] is removed from the tibia by outlining the graft with an incision through the intact periosteum With a one-half to three-quarters inch thin osteotome or shallow gouge a thin layer of bone with its attached periosteum is excised Hypothetically, this graft may be removed in a single flexible piece but actually the bone usually fractures in many places but remains attached to the periosteum This graft of high osteogenic properties is usually used surrounded by additional free bone chips taken

from its tibial origin The osteoperiosteal graft may be readily sutured in place

The Massive or Full thickness Graft Popularized by Albee There are two methods of removing this graft from the tibia after elevating and retracting the periosteum By the use of an electric motor saw, a graft of any width or length may be made If for one reason or another a saw is not to be used, by outlining the proposed graft with drill holes through the cortex of the tibia, the graft may be easily freed with a thin bladed osteotome The drill holes prevent splitting of the tibia Ordinarily, the graft includes the full thickness of the cortex of the tibia An angular or curved graft can be made more easily with the saw, previously outlined by drill holes

The massive graft, while theoretically less osteogenic than the osteoperiosteal graft, has the great advantage of rigidity and continuity of structures Likewise it may be anchored into place by sutures, wires, or screws

Laminated Full-thickness Grafts These are cut like the full thickness massive graft, except that several longitudinal saw cuts, one sixteenth to one eighth of an inch apart, are made so that from two to four separate strips of bone are obtained The thin grafts are moderately flexible and may be placed in any desirable arrangement in the wound

Many orthopedic surgeons now prefer these laminated full thickness grafts when both relative rigidity and flexibility is desired

The Cancellous Graft This graft is taken from the crest or tuberosity of the ilium after subperiosteal exposure The advantages of this graft are numerous It may be obtained through the spinal incision While it has a desirable rigidity and massiveness although less than the full thickness tibial graft, its osteogenic qualities are thought to be greater than the tibial graft Lastly, because of the relatively large amount of bone available in the iliac tuberosity, it can be cut to almost any desired shape The graft can be cut easily with an osteotome without preliminary drill holes

INDICATIONS FOR LUMBOSACRAL FUSION OPERATIONS

In the earlier sections of this chapter on low back pain the conservative therapy has

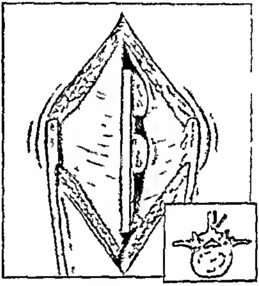

Fig 275 Spinal fusion—Albee Exposed spinous processes are lumbar four and five and sacral one In the midline these spinous processes and interspinous ligaments have been split, the right halves of the spinous processes have been fractured at their bases and a full thickness autogenous tibial graft has been inserted

been discussed If conservative means have failed to control the low back pain or if recurrences are frequent, particularly in those who do strenuous work, stabilization or fusion of the lumbosacral area is indicated when the lesion is considered to be a mechanical one This is true whether it be due to congenital defects (Fig 34), associated with instability or secondary traumatic arthritic changes, or ununited fractures of the arcus or zygapophyses, or localized healed infectious arthritis The fewer vertebrae involved in the operation

the higher is the percentage of successful fusions resulting Whenever warranted these operations should be confined to the fifth lumbar and first sacral segments only

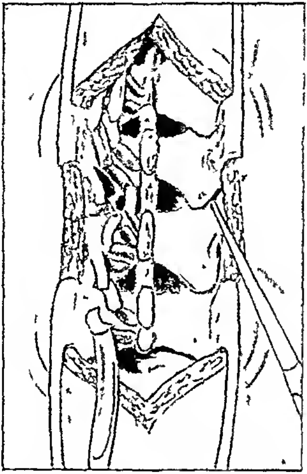

FIG 276 Spinal fusion operation—Hibbs By subperiosteal reflection of erector spinae muscles spinous processes laminae and zygapophyses (articular process joints) have been exposed With curette the articular cartilage is removed from the zygapophyses With a gouge osseous fragments from laminae are freed and interlaced Spinous processes are cut at their bases and displaced downward so that each process is in contact with two raw surfaces

[With this latter statement many men will disagree and will feel that the fourth lumbar should always be included When the lumbosacral angle is at all acute this may be particularly pertinent —Ed]

Albee[18] Spine Fusion—Lumbosacral The exposure differs from the other fusion operations in that no periosteal reflection is made Through a midline incision the spinous processes to be fused are identified —for example lumbars four and five and sacral one (Fig 275) With a broad osteotome the spinous processes are split in a longitudinal line and the bases of the spi

nous processes on one side are then fractured by *tilting the osteotome* *Prior to fracturing* the spinous processes the supraspinous and interspinous ligaments are cut in a longitudinal line to the base of the spinous processes A deep cleft has now been made, into which is placed a full thickness tibial graft cut to the angle and length of the cleft The graft is anchored in place by drill holes through the spinous processes and the graft, or more frequently, by firm apposition of the ligamentous structure with No 1 chromic catgut

The advantages of the Albee fusion are the relative simplicity and brevity of the procedure The chief disadvantage is that the success or failure of the operation depends upon a firm union of a single strut of bone to the spinous processes If the first sacral spine is too small, the graft must be imbedded in the dorsum of the sacrum

Immobilization of the entire lumbar spine and preferably both thighs in a circular or previously made bivalved plaster jacket must be carried out until union of the graft is solid by x ray, usually three to six months

Hibbs[10] Spine Fusion—Lumbosacral A wide exposure of the spinous processes laminae, and zygapophyses (articular process joints) is made Because of the frequent *variations in anatomic structure* of the zygapophyses in the lumbosacral area (Fig 34) this exposure is often quite tedious The posterior capsules of the zygapophyses are now carefully resected as well as the interspinous ligaments and superficial attachments of the ligamenta flava With a small curette, No 00 or 000, or a thin small osteotome, the articular cartilage is removed from the zygapophyses of the desired vertebrae, usually lumbosacral, or lumbars four and *five and lumbosacral* With a one quarter or three eighths inch gouge (Fig 276) the superior and *inferior borders* of the laminae are split off and the bone fragments are incompletely fractured *at their* bases and overlapped with the fragments of the contiguous laminae With a bone-cutting forceps the spinous processes are now cut horizontally at their bases and shifted downward so that each spinous process contacts the raw bases of two processes The wound is now closed in layers [If troublesome and even serious, oozing and bleeding during this operation are to be avoided the exposure must be completely and meticulously subperiosteal —Ed]

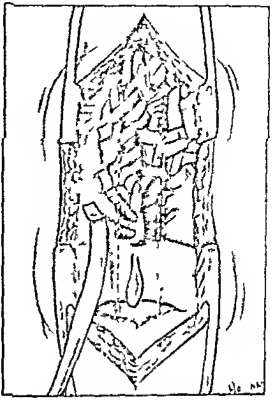

Fig 277 Spinal fusion operation—Mackenzie-Forbes Exposure was obtained by subperiosteal reflection of erector spinae muscles from spinous processes and laminae, and resection of interspinous ligaments A slightly convex raw bone bed is made by fragmenting external cortices of laminae including spinous processes, with a gouge *Dotted line represents position where an autogenous osteoperiosteal or massive graft is placed if desired*

Various modifications of the Hibbs operation are used The most common of these modifications is *the addition of one of the*

several types of free bone grafts Also free bone chips are sometimes placed in the denuded articular process joints

Postoperatively the patient may be placed in a previously prepared bivalved plaster spica or after a period of ten days on a firm bed a jacket may be made Immediate complete immobilization is not necessary After eight to ten weeks the patient may be allowed out of bed in a body jacket or a well fitting steel low back brace Some, including the author prefer to keep the lumbosacral spine immobilized in bed for at least three months or until x rays show fusion to have occurred

Pseudarthroses occur in an appreciable number of cases—a larger percentage if more than one joint is fused and if too early activity is allowed [It is possible that failure to include the thighs at least in the early weeks in the immobilizing jacket may be a factor in causing pseudarthrosis after low spine fusion since hip movements in the supine position in bed may be accompanied by lumbar spine movements —Ed]

Mackenzie Forbes[70] **Fusion** Mackenzie Forbes modified the Hibbs operation because of the difficulty and extra time required for exposure and treatment of the zygapophyses

The exposure of the desired vertebrae is obtained in the usual manner but extended laterally only *to* the zygapophyses (Fig 277) After excising the interspinous ligaments with a one-quarter or three-eighths inch gouge the laminae are fragmented through their dorsal cortices The spinous processes are now split into numerous fragments Correctly done a large uniform bone bed is now obtained with multitudinous interlocking and touching bone fragments

This operation is frequently modified by the addition of osteoperiosteal or laminated full thickness grafts This procedure for lumbosacral spine fusion is preferred by the author and in his experience as well as that of many other orthopedic surgeons has proved to be the ideal procedure

The postoperative care is the same as in the Hibbs operation

Ghormley[71] **Operation** This operation was developed so that its effect might be threefold when indicated In addition to accomplishing a lumbosacral fusion a facetectomy to enlarge the foramen about the fifth lumbar root and a sacro-iliac fusion may be done

An incision about six inches long is made from the fourth lumbar spinous process downward to the lumbosacral area and then carried laterally and downward to about one inch below and one inch beyond the posterior superior iliac spine The laminae of the fourth and fifth lumbar vertebrae the lumbosacral articular facets and the superior surface of the sacrum are exposed subperiosteally The articular facets are removed with a rongeur sufficiently to expose the fourth or fifth or both nerve roots as indicated The dorsal cortex of the fourth and fifth lumbar laminae and the superior surface of the sacrum are elevated with an osteotome By retraction of the skin wound the superior posterior iliac spine and neighboring iliac crest are exposed The gluteal attachments to the crest are reflected down to the superior border of the sacro-iliac notch With an osteotome the bare iliac tuberosity is excised and inserted as a free graft on the denuded laminae of the fourth and fifth lumbar vertebrae and the superior surface of the sacrum A Smith Petersen sacro-iliac arthrodesis is done (See description this chapter) The wound is now closed in anatomic layers Through a transverse incision a *bilateral* facetectomy and sacro-iliac fusion may be done

Postoperative treatment is carried out as in other spine-fusion operations

This operation is indicated especially when there are hypertrophic bone changes from arthritis or trauma narrowing the foramen of the fifth lumbar root and when there are associated sacro iliac signs

Tri sacral Fusion of Chandler [?] In some instances infrequently in the author s

experience, simultaneous fusion of both sacro-iliac joints and of the lumbosacral joint is desired The real indication for this procedure is a combined mechanical instability of these joints However, the operation is used on some occasions when the exact source of the disability in the low back cannot be determined

An incision is made from just below and lateral to one posterior superior iliac spine and curved downward and then upward to a similar site in relation to the other iliac spine After reflecting the skin flap a Hibbs type of fusion is done on the fourth and fifth lumbar and lumbosacral joints, including a bone denudation to below the second sacral spine The midline incision is temporarily closed The skin incision is now retracted to expose one iliac tuberosity An incision is made along the crest to the bone With a broad osteotome the outer table of the ilium with the gluteal origins intact, is reflected laterally by incompletely fracturing the bone The denuded internal half of the iliac tuberosity is resected as a free graft to be placed in the lumbosacral wound The dorsal aspect of the sacro-iliac joint is exposed and the articular cartilage is partially removed with a curette Bone chips removed from the ilium are packed into the sacro iliac joint The outer table of the ilium is now swung down over the sacro iliac joint and the denuded bone surface bridges the sacro iliac joint and contacts the denuded sacrum in this area A similar procedure is carried out on the other sacro iliac joint The wound is closed in anatomic layers [For further descriptions of technic in lumbosacral fusions see Chapters 7 and 14 —Ed]

Sacro iliac Fusions SMITH PETERSEN[23]

With the patient prone and the operative side of the pelvis raised moderately by a small sandbag or folded sheet, an incision is made along the posterior two-thirds of the iliac crest to the posterior superior iliac spine and then extended toward the greater trochanter for a distance of two or three inches The incision is then deepened to the ilium, and the fibers of the gluteus maximus are separated in the line of the lower arm of the incision After detaching the tendinous origins of the gluteus from the iliac crest, the periosteum is reflected from the outer aspect of the ilium with a periosteal elevator to the anterior (middle) gluteal line of the ilium The sacrosciatic notch is exposed taking care not to injure the superior gluteal artery and nerve

The posterior sacro iliac ligaments are now stripped from the area between the superior and inferior iliac spines A rectangular window (Fig 278) is outlined in the ilium, about one by one and one half inches, about one half inch above the sacro sciatic notch The lower margin of the window should roughly parallel the inferior border of the ilium just lateral to the sacro sciatic notch The mesial border of the window may extend to within one half inch of the mesial border of the ilium or preferably, include this mesial margin With a thin osteotome the window is cut through the entire thickness of the ilium until the sacro iliac joint is encountered This site may usually be recognized by the change in pitch or sound and sensation of the mallet striking the osteotome If the window includes the mesial border of the ilium it may be lifted out with relative ease by leverage of a narrow osteotome inserted from the midline The articular surface of the sacrum and the underlying bone to a depth of from one eighth to one-fourth inch is now excised smoothly with a narrow curved osteotome—not a gouge After excising the articular surface from the under side of the iliac plug the graft is now fitted back in the window, and with an impacter is gently, but firmly, driven across the joint line into the sacrum (Fig 278) In order to insure the position of the plug or graft, the margins of the window are turned in over the plug with an osteotome The wound is now closed in anatomic layers

The postoperative treatment is confined

to a period of two weeks' recumbency, followed by the application of a sacro-iliac corset and resumption of patient's activities

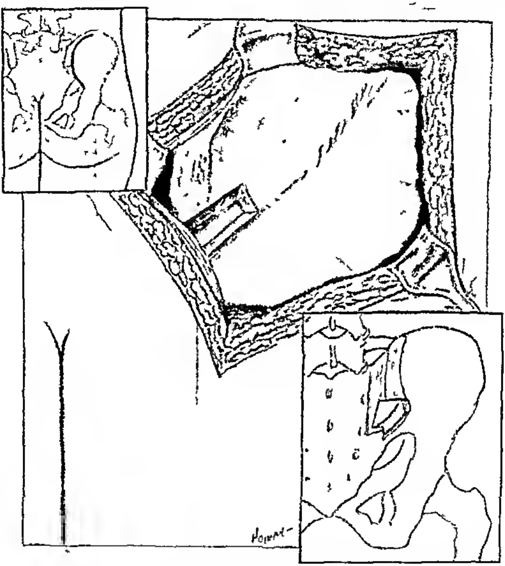

Fig 278 Sacro iliac fusion operation—Smith Petersen Exposure is obtained by subperiosteal reflection of gluteus maximus muscle Skin incision is shown in upper inset *In lower inset posterior third of iliac crest and part of dorsum of sacrum have* been excised to demonstrate relations of countersunk osseous plug to sacro iliac articular surfaces

The great advantage of this operative procedure is that an immediate fixation of the joint is obtained and while healing of the bone is progressing the patient may be ambulatory

Campbell Sacro-iliac Fusion [24] In some instances it is desirable to do an extra articular fusion of the sacro-iliac joint, especially if a tuberculous lesion is suspected, although not necessarily proved With care in this procedure the joint prope need not be opened

With the patient in a prone position, ai

incision is made along the posterior third or half of the iliac crest down to the posterior inferior iliac spine The tendinous and ligamentous structures are now severed in the line of the skin incision Subperiosteal reflection of the gluteal muscles and the sacrospinalis muscles is done so that the tuberosity and posterior third of the iliac crest is completely denuded of soft tissue With an osteotome a graft is removed extending from the posterior inferior iliac spine upward for a distance of about three inches A gutter is made over the sacro iliac joint by excising the mesial osseous overhang of the iliac crest and the dorsum of the sacrum If desired, at this stage the posterior capsule of the sacro iliac joint may be opened, or it may be left intact The iliac graft is now carefully fitted into the gutter, surrounded by additional bone chips taken from the ilium, and the grafts are tamped into place with an impacter The soft tissues are approximated in anatomic layers

Postoperatively the patient is either placed in a previously prepared bivalved double plaster spica extending to the knees, or after a ten day period on a firm bed a circular double spica is made As immediate fixation of the joint is not accomplished by this operation, recumbency with plaster fixation should be continued for at least eight weeks A well fitting steel reinforced low back brace or corset is then applied and the patient is allowed up

GAENSLEN SACRO ILIAC FUSION [73] The indications for this operation, in the author s opinion, are few, inasmuch as it is an intra articular procedure without immediate fixation, such as is accomplished in the Smith Petersen operation, and, likewise, it does not have the advantages of the extra articular fusion of Campbell However, it is preferred by some because if desired the entire articular surfaces of the sacro-iliac joint may be excised

A curved incision is made over the posterior third of the iliac crest The ligamentous and tendinous tissues are incised to the underlying crest With a wide osteotome the outer table of the crest is reflected laterally with its muscles intact The sacr iliac joint is now outlined on the surface of the inner table of the ilium by a triangle The iliac portion of the joint is excised in fragments from which the articular surfaces are removed With a small gouge or curette the sacral articular surface is excised to a depth of one fourth inch or more into the body of the sacrum The iliac bone fragments are now replaced in the triangular hole and tamped firmly Finally the reflected outer table of the ilium is swung back and the wound is closed

The postoperative treatment is the same as in the Campbell sacro iliac fusion operation [For further descriptions of technic in sacro iliac fusions see Chapters 14 and 15 —Ed]

Excision of the Sacralized Fifth Lumbar Transverse Process Infrequently a congenitally large fifth lumbar transverse process (Fig 34) not only articulates with the sacrum but may impinge on the inner surface of the ilium Traumatic arthritic changes may develop in either or both of these sites and be the cause of low back pain However, sacralized transverse processes are not rare, and are usually not symptom producing

When indicated, the offending process may be excised by one of two approaches Through a midline exposure of the lamina by careful lateral dissection, the base of the transverse process may be identified and then resection is done A second approach is through an incision along the posterior iliac crest, denuding the posterior superior iliac spine and excising the spine Then by mesial subperiosteal reflection of the sacrospinalis insertions from the sacrum, the transverse process may be identified As there are several nerves lying immediately anterior to the transverse process, considerable care must be exercised in the excision [This procedure sounds relatively easier and simpler than a lumbosacral

fusion I believe that most men will strongly agree that this is not the case in most instances Not only is the technical procedure more difficult than it sound but the fourth and fifth roots lie directly against the proc

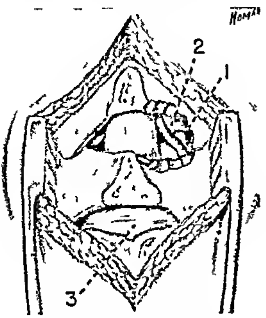

FIG 279 Laminectomy for extradural removal of a protruded intervertebral disk Exact level of offending disk fragment is determined by neurologic examination and lipiodol or air myelographic studies Spinous processes and laminae of the two vertebrae are exposed by subperiosteal reflection of erector spinae muscles Spinous processes are resected with a rongeur after freeing ligamentum flavum (3) an area of the laminae is removed to allow exploration of the nerve root removal of the protruded disk fragment or a hypertrophied ligamentum flavum In illustration dura is shown retracted to left retractor not shown Disk fragment (1) is seen above and beneath posterior nerve root (2)

ess anteriorly are easily damaged and even when handled gently and with circumspection, may give rise to some postoperative causalgia which is anything but pleasant It would appear to be the consensus that a lumbosacral fusion is preferable to excision of the process in these cases —Ed]

Not infrequently there are other anomalies of the lumbosacral area associated with sacralized fifth lumbar transverse processes A fusion of the lumbosacral joint will not only stop motion in the anomalous articulations of the transverse process, but will likewise, control a secondary lesion of the lumbosacral joint Finally, a lumbosacral fusion operation is less hazardous and less difficult than an excision of a sacralized transverse process

Laminectomy for Low back Pain The indications for laminectomy in the presence of low back pain with or without sciatic pain, are the definite signs of nerve root pressure not relieved by conservative means *including* the trial of a body jacket maintaining the lumbar spine in the position of moderate flexion (see Plaster Jackets p 290 and Fig 271)

UNILATERAL LAMINECTOMY With the patient in the prone position the third fourth and fifth lumbar spinous processes and laminae are exposed as in doing a fusion operation In addition it is desirable to expose the zygapophyses The fourth and fifth spinous processes are now excised with a bone cutting forceps If the lesion be a protruded intervertebral disk, as indicated at a definite site by lipiodal or air studies the ligamentum flavum on the affected side is freed from its superior and inferior laminal attachments with a staphylorraphy With a *small* angulated double-action rongeur the inferior half of the upper lamina and the superior half of the lower lamina are excised to the articular processes but carefully preserving the continuity of these processes (Fig 279) [Small bites should be taken with the rongeur, and it should be carefully placed for each bite, as it is not too difficult to injure the dura at this stage —Ed] The freed ligamentum flavum is now grasped, severed near the midline retracted dorsally and resected as far as possible from under the articular processes Hypertrophy or variation from the normal pale yellow color is noted By gentle mesial

retraction of the dura the fourth or fifth lumbar root *must* now be identified If the nerve root has been the site of compression it may appear congested and swollen, or even flattened or indented at one point The lateral attachment of the ligamentum flavum to the articular process is now completely resected By continued mesial retraction of the dura, and upward and then downward circumspect retraction of the nerve root, a protruded intervertebral disk fragment may be identified as a rounded protuberance Moderate oozing may be encountered at this stage of the exploration, and if it is not controlled by saline irrigation and aspiration, firm pressure with a cotton pledget will usually suffice If a protuberance is found it is grasped with a hemostat and with gentle traction it is lifted out from the intervertebral area With a hemostat the resulting cavity is gently explored for an additional annulus fibrosus fragment To release the lipiodal the head of the table is raised about six to 12 inches and between silk sutures the dura is incised After the lipiodal has escaped, the dura is approximated with silk sutures and the wound is closed in layers [This is really a partial hemilaminectomy of the adjacent margins of the two laminae Removal of the whole lamina in this condition has been generally discarded Many men find it unnecessary to remove the spinous processes —Ed]

Bilateral Laminectomy This approach yields a better exposure, is preferred by many surgeons, and is definitely indicated when a centrally protruded disk is suspected or found, and when no protrusion is found by the smaller exposure

[In the minds of many, a bilateral partial hemilaminectomy without removal of the spines is preferable —Ed]

After excising the fourth and fifth spinous processes, at the desired level, the ligamenta flava are detached from the upper and lower surfaces of the lamina With the curved rongeur both sides of the laminae are resected to the articular processes The ligamentum flavum is cut in the midline and the halves are resected The dura is now opened between stay sutures The caudal filaments are gently retracted and the protruded disk fragment is identified under the anterior dural wall When and if identified, the anterior dural wall is incised and the disk fragment or fragments are gently pulled out The dura is closed and the wound is closed [Meticulous care against bleeding into the dural canal is indicated as blood retained therein is apt to produce postoperative causalgia Silver clips are used in place of ligatures The dura closure should be with fine silk —Ed]

The postoperative treatment must include the usual precautions taken in the presence of temporary neurologic disturbances consequent to spinal canal surgery If convalescence is uneventful recumbency is indicated for a period of from 2 to 4 weeks depending upon extent of surgery When allowed up the patient wears a Williams type back brace for 2 to 4 months

Occasionally it is necessary to sacrifice a zygapophysis or articular process in order to complete the exploration or removal of the disk fragment Likewise, prior to operation, a mechanical instability of the lumbosacral area may have been noted Under either of these circumstances, at the time of laminectomy a fusion procedure with the use of a bone graft is indicated

[The technic of laminectomy is here included because the surgery of lesions of the disks and the nucleus pulposus deals with a pathologic process in the spine Neurologic structures are not involved except by pressure exerted by the pathologic spinal condition At the same time it should be noted that the handling of the dura and the roots must be meticulously gentle, and that hemostasis by clips bone wax the use of muscle tabs and the employment of moist half inch strips of packing in conjunction with a small sized sucker in the wound is essential —Ed]

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10

Affections of Muscles, Fasciae, and Tendons (Except Tumors and Trauma)

CLAY RAY MURRAY, M D

MYOSITIS (MYOFIBROSITIS FIBROSITIS, MYOFASCITIS)

Under this term are to be included a number of conditions characterized by subjective pain tenderness, and stiffness in various muscles and objectively by localized areas of acute deep tenderness associated with palpable localized nodular indurations and with spasm of the affected muscles not directly associated with trauma

In the neck region this results in the so called stiff or wryneck affecting principally the trapezius and less often the sternocleidomastoid muscles Here it must be differentiated from true torticollis in children (see p 313) as well as from spasm associated with tender and painful lymphadenitis of the cervical nodes and other conditions resulting in simple protective muscle spasm In the back region the posterior scapular muscles the paraspinal group or the lumbar muscles (lumbago) may be involved In the lower extremity the glutei the thigh flexor knee extensor group, the hamstrings or the calf muscles may be affected and in the upper extremity the biceps and the wrist and finger extensor group are sometimes involved In the extremities this is frequently referred to as charleyhorse or muscular rheumatism

The diagnosis is made entirely too frequently, and is applied to the painful muscle spasm which accompanies and often masks far more serious underlying conditions Before this diagnosis is made one should be certain that this is not the case Postural defects habitual strains bone and joint disease and tumors bursal affections and similar conditions are frequently missed by the superficial examination which results in the diagnosis of myositis or neuritis The diagnosis of myositis should not be made unless definite localized areas of acute deep tenderness with induration can be demonstrated

The painful and tender indurated areas are said to show congestion edema and round-cell infiltration

TREATMENT

1 Heat This can be used in the form of (a) radiant heat (b) diathermy, or (c) wet applications

RADIANT HEAT This can be employed by the use of the so-called therapeutic or heat lamp, or the infra red lamp The common error is to use too high a degree of heat for too short a time Moderate degrees of heat used an hour or more at a time are more effective in securing what is indicated which is muscular and vascular relaxation The electric pad or hot water bags can be used to prolong the effect between radiant heat treatments, and should also be used at mod

erate temperatures Overuse of heat in refractory cases of this type is common resulting in mottling and pigmentation of the skin

DIATHERMY Long or short wave diathermy can be used The latter is more popular at the moment Diathermy should be regarded definitely as a form of heat application the heat being generated in the muscle tissue and not as a form of electrical treatment As a form of heat generated in muscle it has definite harmful potentialities It is very frequently used too intensively and very frequently does more harm than good when so used The criterion for milliamperage is frequently the patient s appreciation of a sense of heat in the treated part This is basically unsound The purpose of treatment is not to make the affected part feel hot but to relieve pain and spasm and the criterion should be *the lowest milliamperage* which will give the patient relief of his pain and tightness *It is not at all necessary* for the patient to feel heat in the part In general milliamperage should never be above 500 and usually the desired effect may be secured with 150 to 250 if the treatment is continued for 30 minutes to an hour Prolonging the time of treatment at 250 milliamperes is much sounder therapy than increasing the milliamperage (See discussion of physical therapy in fracture treatment Chapter 22)

WET HEAT This is best used in the form of comfortably hot wet compresses well wrung out and replaced as soon as they begin to cool The idea is to maintain a continuous and even degree of moist heat Short intensive treatments are not indicated Bath towels and large wash cloths are ideal for this purpose Thirty minutes to an hour should comprise a treatment period

2 Static Brush This will often help to relieve pain and spasm If it increases these symptoms as sometimes it seems to it is probably being used too intensively for the individual case The tendency to overintensively treat is common with this medium

3 Massage Following the use of heat or static brush as described above progressively deep kneading massage to the tender and indurated areas may be used The success of many athletic trainers in the treatment of charleyhorse is dependent upon the skillful carrying out of this form of treatment Results are frequently attributed to the use of the rubbing solution employed as an adjuvant just as the success of properly used wet heat is frequently credited to the solution used in the compresses

The secret of successful massage in these cases is gradually increasing depth and pressure concentrating on the localized areas of tenderness ultimately using the thumbs and the heels of the hands This obviously takes time Superficial massage of the so-called sedative type useful in pure muscle spasm does not produce results in these cases Immediate deep kneading certainly does not produce relief from pain tenderness and spasm A skillful masseur should secure definite relief from pain tenderness and spasm by the end of a treatment if massage is to do the patient any good

4 Local Anesthesia INFILTRATION METHOD Five to 20 cc of an 0 5 per cent or a 1 per cent novocaine solution is slowly injected into each localized tender and indurated area until the tenderness disappears A deep kneading massage followed by a period of active exercise should follow The mere injection of the anesthetic is much less apt to be effective Other local anesthetics some of which have more prolonged effect than novocaine may be used The value of the local anesthesia lies partly in its relief of pain and spasm but largely in allowing vigorous massage and vigorous active motion It may be repeated several times at daily or longer intervals If symptoms keep recurring after a few injections with following massage and exercise or if massage and exercise are prevented by pain despite the injection some cause for symptoms other than so called myositis should be sought

The use of local anesthesia as a direct curative agent is in general, overdone, and its value as a means of securing adequate deep massage followed by active exercise is in general too much neglected

SURFACE ANESTHESIA The spraying of the skin over the areas of tenderness and induration with ethyl chloride will frequently result in sufficient alleviation of muscle spasm and local tenderness to allow of adequate massage and active exercise in the absence of actual underlying disease A great deal has been said and written about the mechanism whereby this effect is secured Whether it be through psychic influences or through a reflex arc mechanism is here beside the point It is however, an empirical fact that the effect can be secured It is also a fact that the mere temporary elimination or diminution of pain and tenderness is not the desideratum of the procedure It is merely a means whereby adequate deep massage and active exercise of the involved muscles may be secured

The spray should be used short of freezing the skin, and the skin should be protected beforehand by the application of an oily solution—ordinary camphorated oil is very satisfactory The areas of tenderness are mapped out and marked Each area is alternately sprayed and palpated until the tenderness is gone The palpation is made progressively firmer until it becomes a deep kneading finger massage and should be accompanied by intervals of progressive active exercise by the patient as and if the pain and spasm diminish As one tender area is relieved by the treatment others may become apparent, and must be sought for and similarly treated (See local anesthesia in the treatment of sprains Chapter 41)

If gradual deep massage and active motion are not made possible by careful carrying out of this procedure, it should be abandoned and some cause for symptoms other than mere myositis should be looked for

Freezing of the skin must be meticulously avoided in using the spray

The procedure cannot be carried out rapidly A treatment will take an hour or more and the active cooperation of the patient is obviously essential

The relief of pain and spasm by all of these procedures is primarily to allow of active exercise and massage of the affected muscle or muscles with resultant increase in circulatory efficiency Unless this is kept in mind and made the primary purpose of treatment, the procedures outlined will give temporary relief only and the symptoms will promptly recur The patient should be made to understand this thoroughly

For symptomatic relief aspirin in doses up to 15 grains at three or four hour intervals, or, in particularly severe cases combined with codeine phosphate in small doses is helpful although not curative

MYOSITIS OSSIFICANS

Of the two forms of this disease the progressive generalized type is not amenable to any form of treatment

For the localized form which follows direct trauma to muscle or complicates certain fractures see Chapter 22

SNAPPING HIP

When either the annoyance of the constant snapping on flexion adduction, or internal rotation or the associated pain furnishes the indication the following procedures are indicated

1 Simple division of the tight and thickened fascial edge, usually the posterior border of the sheath of tensor fasciae femoris or the anterior upper border of gluteus maximus insertion into the greater tuberosity This should be followed by early active mobilization

2 Incision of the posterior portion of the iliotibial band and transference forward to the anterior thigh fascia after freeing the lower end of the tensor fasciae femoris

Except in severe cases the former procedure usually suffices

Local anesthesia is to be preferred, since

the patient can demonstrate the snapping and the offending edge can readily be recognized

The incision runs along the posterior border of the tensor fasciae femoris and the posterior border of the greater trochanter

If the superior border of the gluteus maximus insertion is found to be the offender it can be sutured directly to the greater trochanter edge up to the point where it no longer snaps back and forth on movement (Jones)

Procedure 1 above can be varied by transverse section of the fascial band at the lower level of the greater trochanter distraction of the edges for one half to one inch relieving the tension and suture of the distracted edges to the greater trochanter to prevent re union and contracture with recurrence of tension (Mayer)

All procedures should be followed by as early mobilization as is consistent with wound healing

Differentiation must be made from conditions producing sensation of click or snap but due to intra articular disturbances in the joint

Occasionally coincident resection of a trochanteric bursa inflamed or irritated by the snapping back and forth of the tight band must be carried out

The condition usually requires operation only when bursitis induces pain or when the patient is upset through painless but persistent snapping

SNAPPING SHOULDER

This may be caused by one of the following conditions

1 The fibers of the short head of the biceps as they pass to the coracoid process snapping over the lesser tuberosity in abduction and external rotation This is a congenital anomaly

2 Subluxation of the biceps tendon from its groove during rotations or in abduction particularly in external rotation

3 Snapping of the taut edge of the coraco acromial or coracohumeral ligaments over the edge of the humeral tuberosities in external rotation and abduction

The symptomatology is that of a palpable or audible snap with or without pain The indications for treatment are pain or the annoyance caused by the constant snapping

The treatment is surgical and consists in eliminating the mechanism In groups 1 and 2 above the taut edge of the muscle tendon or ligament is incised In the second group the biceps tendon can be anchored in its groove by roughing up the under surface of the tendon and the bed of the bicipital groove and fastening the tendon to the margins of the groove by two or three silk sutures The institution of active motion in the latter case should be gradual a sling and swathe being used postoperatively Full active motion should not be allowed for six weeks

These cases if operated on should be done under local anesthesia so that the offending mechanism can be recognized at operation as the patient goes through the motion which causes the snap This is the only way to positively identify the mechanism involved

All such cases should be x rayed before operation since occasionally an exostosis or bony growth or prominence may be revealed which is a component part of the mechanism Such x rays should be taken in both internal and external rotation of the shoulder

SNAPPING JAW

This condition results from displacement or tear of the intra-articular meniscus of the temporomandibular joint It is frequently bilateral When painful, or sufficiently bothersome the meniscus should be removed Since the joint lies under the zygomatic process directly in front of the upper edge of the lobe of the ear, the incision should start at that point and extend forward about one and one-half inches just below the inferior border of the zygoma

Careful minute dissection should be used to avoid damaging the branches of the facial nerve and the nerve branches should be kept in mind in retraction The exposure of the joint and the excision are best carried out with the jaw opened The joint capsule should be opened longitudinally and not transversely

Where the condition is painful the excision is a wise procedure since arthritic changes in the joint itself may ultimately result in motion limitation

SNAPPING NECK

Occasionally a patient complains of a painful and palpable sometimes audible snap in the back of the neck on extension This is caused by friction between the cervical spines The fifth and sixth spines are the usual offenders and the treatment consists in the removal of the major part of the upper of the offending spinous processes through a midline incision

SNAPPING KNEE

There are five usual causes of this condition

1 Congenital or acquired laxity of the ligaments particularly the internal collateral or anterior crucial ligaments In such cases the movement can be voluntarily produced in certain positions by the patient, usually during sudden extension and the tibia snaps outward or forward on the femur In infancy this may be involuntary

2 The biceps tendon occasionally snaps over the edge of the fibular head during movement

3 There is occasionally an exostosis or osteoma of the upper end of the fibula which interferes with biceps tendon mobility and is responsible for the snap

4 The so called discoid type of lateral meniscus coupled with undue mobility of the meniscus may be the cause

5 A normally formed meniscus which is loosely attached may be the responsible agent

In infants in whom the involuntary snap occurs firm bandage support—or in extreme cases the use of a supporting brace is the treatment indicated The latter treatment is rarely necessary and surgery is never indicated

In the adults in whom the internal collateral ligament is relaxed resulting in an outward snap whether the relaxation be congenital the result of repeated strain or of a single severe injury reefing or other repair of the ligament is indicated (See Chapter 38) When the forward jump of the tibia occurs it is usually due to anterior crucial relaxation and instability allowing the forward displacement of the tibia on the femur in the right angle flexed knee is demonstrable In such cases anterior crucial repair is done (See Chapter 38) This is probably the only indication for repair of that ligament

Where slipping biceps tendon is the responsible agent the curative operation consists in fastening the biceps tendon to the fibular head at or just above the point where the slipping can be demonstrated

An exostosis on the upper fibula calls of course for removal It is to be remembered that all exostoses or osteomas should be removed together with the underlying cortex and not flush with the cortical surface as otherwise they may recur

When the condition is due to a loose or discoid cartilage giving signs of a meniscus disturbance arthrotomy and removal of the offending meniscus is indicated (See Chapter 38)

The frozen shoulder, also known as periarthritis about the shoulder, adhesions about the shoulder, and often confused with bursitis is discussed in connection with shoulder girdle injuries in Chapters 15 and 29

The contracture of the gluteal fascia and of the fascia lata and tensor fascia femoris associated with the symptomatology of low back pain and sciatica and pyriformis con

tracture with the same significance, are discussed in Chapter 9

In addition to the tendon tumors which may occur there are tendon degenerations independent of trauma which may occur in various tendons quite similar to those seen in the tendons of the musculotendinous cuff in the shoulder so interestingly described by Codman and others They may be associated with soft calcific deposits under tension, and may be quite painful They occur near or at the insertion of the tendon Calcification may not be present If not cared for, the weakened tendon insertion may rupture with little violence or without violence other than normal muscle action These have been seen and noted with and without rupture in many tendon insertions including the tibialis anticus and posticus the flexor carpi radialis and flexor carpi ulnaris the Achilles tendon the radial and ulnar carpal extensors the subscapularis tendon and the triceps tendon They occur almost invariably in people over 45

Since the calcium deposit if present, is merely an incident secondary to degenerative change these lesions are best treated by surgical exploration removal of the calcium deposit if present and removal of degenerated tendon areas with repair of the resultant deficit The repair of the tendon is much easier before rupture than subsequent to rupture Prolonged conservative treatment of such painful tendon insertions is not indicated If prompt response to conservative measures is not evident the surgical procedure indicated above should be resorted to

In the Achilles tendon in individuals over 45 one occasionally sees extensive degeneration sometimes with bleeding into the tendon resulting in a painful and tender tendon which is characterized by palpable and often visible lumpy thickenings X rays are negative except for visible knobbiness of the tendon if the soft part shadows are well shown These tendons are quite prone to rupture without known trauma When seen in the stage described above conservative therapy is not so well advised as is surgical excision of the degenerated areas with plastic repair of the tendon utilizing if necessary fascia lata to reinforce the repair

For methods of tendon repair and suture see Chapter 42

Tendon contractures may require tendon lengthening procedures Their technic is described in Chapter 42

Stenosing tenosynovitis of tendon sheaths occurs almost exclusively in the fingers of the hand, except for that variety described by Quervain involving the common extensor sheath of the extensor longus pollicis and extensor brevis pollicis as they cross over the postero-external aspect of the lower end of the radius beneath the dorsal ligament While in some instances a specific trauma may be provable in most cases the etiology is either not known or not definite In the fingers it results in the so-called trigger finger or trigger thumb The ring and the middle fingers are most often involved There may be pain or stiffness associated with the characteristic trigger mechanism—a block in flexion, followed by sudden release and extension The obstruction is usually at the metacarpophalangeal joint level, but may occasionally occur at the level of the interphalangeal joints Occasionally the block and sudden release occur during both flexion and extension

The treatment is simple and effective It consists in exposing and incising longitudinally the flexor tendon sheath at the point of constriction or obstruction Occasionally the block is caused by thickening of the tendon rather than by constriction of the sheath but the procedure in either case is the same If the line of skin incision crosses the joint crease, it is well to remember that it should do so transversely

In the type described by Quervain at the wrist some difficulty and discomfort in thumb abduction some swelling and point tenderness over the radial styloid and pain at that point on ulnar deviation of the hand

ure characteristic Longitudinal splitting of the thickened tendon sheath gives complete relief

SLIPPING PERONEAL TENDON

This may occur in poliomyelitis with a calcaneus deformity, but is of no special significance here It may occur as the result of acute injury Manual replacement is usually possible followed by a thin skin fitting plaster boot for two or three weeks Where the slipping is habitual and painful causing disability the groove which it occupies in the back of the fibula may be deepened and the sheath with if necessary the aid of a fascial strip may be fastened in the deepened groove In habitual cases the tendon may be shortened, interfering with dorsiflexion In such cases tendon lengthening should be done (See Chapter 42) Three weeks' protection is indicated during the postoperative period

A noninfectious and nonsuppurative tenosynovitis may occasionally occur as the result of apparently normal or over use This usually involves the thumb extensors the common finger extensors beneath the carpal ligament the finger flexors at the wrist and the peroneal tendons behind and below the fibula or the Achilles tendon It is usually associated with some swelling and tenderness, and frequently with a soft crepitus on motion of the affected tendon The treatment is rest by splinting hot soaks and the use of static brush and diathermy If response to this therapy is poor and disability continues the case should be carefully reviewed for etiologic factors of a disease nature since this type of tenosynovitis should respond rapidly to the therapy indicated

TORTICOLLIS (WRYNECK)

This condition may be congenital or acquired The latter is by far the more frequent form and comprises roughly 80 per cent of all cases Except for the unusual spasmodic type which is a disease of adult life (see below), the great majority of acquired cases appear before the tenth year of life

Congenital Form This may be of two types and it is important to make certain which type exists before attempting treatment

The uncommon type of congenital torticollis is a primary congenital deformity associated with other congenital defect Fusion of the atlas to the occiput or of the axis to the atlas failure of segmentation of the cervical vertebrae associated with the Klipper Feil syndrome anomalous cervical vertebrae (including hemivertebra) and cervical ribs are frequent in this type It is wise therefore to exclude these condition by adequate x ray investigation in all congenital forms before undertaking treatment since harm can result from manipulation in these cases and no benefit can be gained by operation on the muscle without correction of the bony abnormality

The common type of congenital torticollis without bony defect or abnormality if recognized in early infancy is often readily amenable to correction by manipulation methodically carried out over a varying period of time followed by plaster retention in the overcorrected position when and if overcorrection is obtained Corrective exercises are used for a long period after removal of the plaster in order to maintain the correction

The milder cases will often yield to manipulation alone It is important that not too much force be used in these manipulations They can be carried out with the patient in either a sitting position or lying with the head over the end of a low bed or couch and resting on the hands or knees of the doctor The manipulation aims to slowly stretch the affected sternocleidomastoid muscle within safe limits and is carried out by turning the chin toward the affected side and elevating it bending the head away from the affected side and by attempting to approximate the ear of the sound side to

the region of the sternoclavicular joint Moderate traction is maintained during the procedure It is performed slowly Heat and massage to the affected muscles are advisable following it Daily treatment is indicated and should be augmented by active exercises by the patient

In the more severe cases and in those which fail to yield to this procedure manipulation of the same sort under anesthesia with due care to proceed slowly and with circumspection may gain complete or partial correction This is maintained by a plaster jacket including the head and extending to the iliac crests If only partial correction is obtained a further attempt at complete correction is made in a couple of weeks and a new jacket applied When complete correction is attained the plaster is worn for from four to eight weeks in the overcorrected position It is then removed and a regime of daily active exercise and massage is instituted to maintain the correction The exercise is the active voluntary simulation by the patient of the movements of the manipulation It is extremely important that these be continued for a long period as recurrence of the deformity may otherwise take place

It is also important to recognize that varying degrees of cervical scoliosis may accompany or result from the torticollis and to direct exercise and correction to this simultaneously with the treatment of the affected muscle

Exercises or corrective appliances without preceding manipulative reduction are of little or no value If these conservative measures fail the operative treatment described below is indicated Operation should not be done except in extremely severe cases before the child is three years old The early recognition of the condition and the institution of adequate conservative treatment in the early stages may frequently eliminate the necessity for operation so often unavoidable when the contracture becomes well established

Acquired Form In the acquired cases in older children adolescents and young adults it is wise to make sure that no extraneous cause for torticollis is present The conditions which should be eliminated by examination are tuberculosis or arthritis of the cervical spine cervical lymphadenitis inflammatory ear conditions poliomyelitis and visual and ocular muscle defects The latter should always be checked in torticollis cases

As a result of sudden twistings of the neck children are very subject to unilateral rotary forward subluxations usually between cervical two and three or cervical three and four The picture is strikingly like that of torticollis except that the pain and the spasm in the neck muscles are on the long side of the neck instead of on the short side as in true wryneck (See Chapter 26 on Fractures and Dislocations of the Spine)

Some of the milder acquired cases of not too long standing are subject to correction by the conservative measures described for the congenital ones

Operative Treatment A number of operations have been devised for the correction of torticollis It is probably unnecessary to state that subcutaneous tenotomy is never justified and should never be resorted to An open operative division of the muscle is indicated Lange and Putti advocated division of the upper end of the muscle just below the mastoid in the belief that better correction could be attained than by the division of the lower end since the muscle was often adherent to its sheath below The location of the scar covered by hair was also considered an advantage The procedure is not today advocated however and is not here advised The spinal accessory nerve and the external jugular vein may be injured in the upper approach and excessive overcorrection which may be harmful is too easy to attain

It is today conceded that adequate division of the lower attachments is the proper procedure The incision parallels the clavi

cle from just to the inner side of the sternal attachment to just to the outer side of the clavicular attachment The fascia and platysma are opened in the same line as the skin incision and the two heads of the muscles are completely exposed The anterior jugular vein runs anteriorly and medial to the sternal head and the external jugular vein runs posteriorly to the clavicular head in a line extending from the mastoid to the middle of the clavicle The sheaths surrounding each head are split well up longitudinally and the muscle bellies are carefully dissected free from the sheath Each head is then severed close to its bony insertion The sheath is then severed transversely In some cases it may have to be dissected free from the underlying tissues to which it is adherent The division of only one head or of the muscles alone without the sheath or of the muscles and sheath without first dissecting the former from the latter are unsatisfactory procedures It should be remembered that the posterior sheath covering the outer end of the clavicular head lies over the internal jugular vein but the vein is placed deeply and should not be in any serious danger if the procedure is carried out as described

Following the division of the two heads of the muscle and its sheath the deformity should be thoroughly overcorrected by manipulation, and any curvature of the cervical spine should be eliminated A plaster jacket including the head and extending down to the iliac crests is applied in the overcorrected position This is worn for from six to eight weeks depending on the severity of the case When it is removed, the exercises previously described are instituted together with manipulation and massage The manipulation should be done daily and the exercises several times a day for several weeks at the end of that time the exercises alone will usually be adequate It cannot be too strongly emphasized that mere tenotomy is not a curative procedure The overcorrection, the correction of spinal curvature the wearing of the corrective plaster for from six to eight weeks [illegible] the passive and active exercise in overc[illegible] are essential to permanent succes[illegible] cases should be kept up several ti[illegible] for a minimum of six months an[illegible] cases for as long as a year Fail[illegible] the patient s or the parents full co[illegible] in this may result in gradual recurr[illegible] the deformity

If correction is adequate and [illegible] tained the facial asymmetry char[illegible] of this condition clears up with [illegible]urpr[illegible] rapidity and will completely d[illegible] in the younger cases

A muscle lengthening may be suf[illegible] get adequate correction This is best d[illegible] by sectioning the clavicular head [illegible] its insertion into the bone and the sternal head at the point where it joins the clavicular head above The muscles are dissected free from their sheath and the proximal stump of the clavicular head is sutured to the distal stump of the sternal head the proximal end of the sternal head being left free There seems little or no advantage in this procedure The value of the lengthened muscle over that treated by simple division is debatable and the procedure has to be followed by the same routine as the simple division to assure success

Spasmodic or Spastic Torticollis. This occurs in adults as clonic contractions involving the sternocleidomastoid on one side and the posterior muscles on the opposite side These may be sudden and violent or slow and rhythmic It is a progressive condition and responds to no treatment designed for torticollis Retentive apparatus or manipulation frequently intensifies the spasm It may be very painful A Thomas collar may sometimes help Correction of ocular and visual defects and the elimination of irritative lesions in the nose throat mouth and ears are indicated Active exercises for the antagonizing muscles sometimes help In intractable cases division of the spinal accessory at its exit from the

jugular foramen plus section of the roots of cervical one, two, and three at their entrance into the dura has been practiced unilaterally and bilaterally It is a procedure calling for expert neurosurgical skill and an intimate knowledge of the anatomy involved

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11

Affections of Bursae and Ganglia

GUY A CALDWELL M D

GANGLION

The methods of treating ganglion vary from advising complete neglect to the most thorough and painstaking excision Any or all of the methods advocated may be quite rational because of the unusual character of the lesions

Ganglia are benign cystic tumors usually multilocular occurring most often on the dorsum of the wrist (Fig 280) or ankle Other sites are the knee and volar regions of the fingers and the hands (see Fig 281) The walls which may be either thin or thick are usually attached to either a joint capsule or a tendon sheath and the cavity is filled with jelly like material These ganglia vary in size from that of a small pea to several centimeters in diameter At least half of them are practically symptomless very few progress to the point of producing real disability, and none has become malignant or resulted in serious complications

Of those seen in the early stages approximately half disappear spontaneously, never to recur Because of the few symptoms slow progress rare disability, absence of complications or serious sequelae and the strong possibility of spontaneous disappearance it is most rational to advise judicious neglect of the early cases

Many of these tumors are seen among women in the second third and fourth decades who object to even slight discomfort These patients are eager to have the unsightly "knot" removed but object to a scar as much as to the original lesion In such instances one may consider the time honored but crude method of breaking the ganglion by resting the arm on the table and forcibly rupturing it with a book This accomplishes a rupture of the sac with dispersion of the jelly like contents and subsequent absorption with successful results in about half the cases Reappearance of the tumor may occur, however as a result of expansion of some of the small cyst cavities which were not completely ruptured Rupture of thin walled sacs may be accomplished by direct pressure of the thumb with or without the preliminary injection of novocaine about the sac

Dispersion of the cyst contents and collapse of the sac can be obtained by puncture and aspiration with needles of various sizes Before the cavity is punctured an injection of novocaine 2 per cent should be given intradermally and subcutaneously The object is to transfix the tumor in various directions with a needle of large bore After it has been punctured a number of times as much material as possible should be aspirated from the cyst cavity, the needle should be withdrawn and the portion which remains massaged rather vigorously in an effort to express it through the needle holes out into the subcutaneous tissues where it may be absorbed (Fig 282) Following aspiration and massage of the punctured cyst the

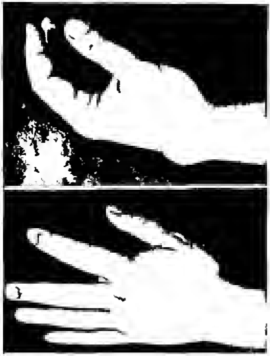

Fig 280 Dorsal carpal ganglion (Courtesy Mason M L Surg, Gynec and Obstet 64 131)

part should be placed on a splint in a position which formerly made the tumor most prominent A gauze or sponge rubber pad should be put over the collapsed tumor and bandaged in place with moderate pressure The splint and pressure bandage should be employed for several days, after which the patient may gradually resume use of the part

After aspiration of the ganglion some men have injected small amounts of tincture of iodine 3 5 per cent or metaphen into the sac These chemical irritants in some instances have brought about a sclerosing action with obliteration of the cyst cavity In the hands of others however, it has been found dangerous, because the material may be injected into a joint cavity or tendon sheath and produce rather severe reactions followed by numerous adhesions The pain and disability following the escape of these chemical irritants into a joint cavity are frequently serious and persist for many weeks It is doubtful whether their use is ever

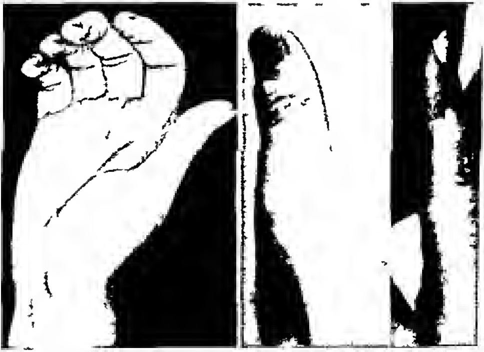

Fig 281 (*Left*) Volar carpal ganglion (*Center* and *Right*) Ganglia of distal interphalangeal joint capsule (Courtesy, Mason M L Surg, Gynec and Obstet 64 131)

indicated If used one should be certain that the point of the needle is in the cyst cavity and has not penetrated beyond A very small amount of the chemical irritant should be injected and very little pressure made over the mass after the needle is withdrawn [The solutions commonly used for sclerosing varicose veins have also been used *The Editor agrees with the author* as to the inadvisability of the use of this method of treatment —Ed]

When the *tumor* has *persisted* for a long time when it has not responded to breaking or puncture and when pain and weakness of the joint or *unsightliness* are *sufficient* to constitute a real disability operative removal of a ganglion should be considered The late results following surgical removal indicate that the procedure is not uniformly successful Reappearance of the tumor occurred in *31* per cent of the cases followed by Carp and Stout Analysis of the reasons for reappearance suggests that the dissection and removal were not thorough

There is no margin of safety in dealing with ganglia at operation because they are always in close proximity to a joint capsule or tendon sheath The operation of excision should never be undertaken except when complete asepsis is assured and adequate facilities are available

Unless the set up is unusual it is unwise to attempt *ganglion excisions as an office* procedure Help in retraction is usually needed and if infection occurs the results may be serious because of involved tendon sheath or joint cavity The necessary dissection may be slow tedious and extensive

Skin preparation should be thorough lighting well directed and a tourniquet used to keep the field bloodless Transverse incisions should be *employed to avoid unsightly* scars The wound should afford adequate exposure and the dissection should be carried down carefully to avoid rupture of the cyst until the base has been carefully dissected from capsule or tendon sheath Excision of a portion of the joint capsule or of a tendon sheath is often necessary to obtain complete removal of the sac *No* attempt to close the defect in capsule or synovial sheath should be made Before closing the tourniquet should be released and bleeding points caught and tied The wound should

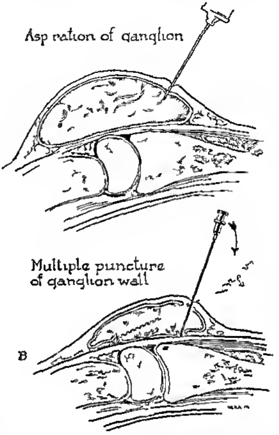

Fig 282 Technic of aspiration and *multiple puncture*

be closed in layers A splint should be applied with the joint in a position of relaxation and the splinting continued for from one to two weeks Finger motion may be instituted very early together with light massage but motion of the wrist joint should be somewhat delayed when portions of the capsule have been removed in the course of the operation

If the operation has been carefully and *thoroughly carried out* as *described* there can be very little reason for reappearance of the tumor On the other hand it is not *uncommon* to have the patient complain of

some discomfort of the part or slight restriction of joint movement for some months after operation and occasionally when the scar tissue is in the vicinity of a nerve there may be constant complaint of pain following the operation

Occasionally what is thought to be a ganglion on the dorsum of the wrist turns out to be a tuberculous tenosynovitis This may be recognized or suspected at operation by the finding of rice bodies in the sac, by marked attenuation of the tendons, or by the fact that there is no distinct pedunculated sac but instead a general irregular enlargement of the tendon sheath The tissue removed by excision should always be examined microscopically if any of these suspicious findings are noted and if tuberculosis is demonstrated in the sections x ray therapy is indicated postoperatively

BURSITIS

Treatment of bursitis depends upon the location of the involved bursa the character of inflammation (acute or chronic traumatic or infectious), and the facilities available for treatment

The early reaction of a bursa to trauma is the simplest form of acute bursitis Aspiration to relieve tension splinting to provide rest and the use of a pad and elastic bandage to maintain moderate pressure over the collapsed sac constitute adequate initial treatment The splinting and pressure bandage should be used continuously, keeping the part elevated and completely at rest, until the swelling and tenderness have diminished or completely disappeared Gradual use of the part may then be permitted preferably with continuance of intermittent splinting If pain or swelling do not recur, full motion then may be permitted

If acute bursitis is improperly treated, or if repeated injuries occur, the bursal sac distends, the walls thicken the process becomes chronic, and resolution is not likely to follow the simpler measures of treatment For this reason, complete excision of the chronically enlarged and thickened bursa is usually required If excision is the procedure selected, hemostasis should be thorough, closure accurate, and the part splinted with the cavity from which the bursa was excised completely collapsed with the aid of a pad and pressure bandage During the early stages of repair, splinting and elevation of the part should be continued Gradual resumption of activities may be started 10 to 14 days postoperatively Recurrences following excision may be the result of incomplete removal of the sac or of not keeping the cavity collapsed while healing

Subdeltoid Bursitis

The large bursa over the head of the humerus underlying the deltoid muscle and the acromion arch is really one continuous bursa although variously described as the subacromial or subdeltoid bursa Acute symptoms develop when this bursa is subjected to direct or indirect trauma and when the supraspinatus tendon is ruptured or undergoes degenerative change, with or without calcium accumulation

ACUTE SUBDELTOID BURSITIS

During the acute stage the injection of novocaine followed by aspiration of fluid from the bursa frequently gives spectacular relief Mitigation of pain often ensues even when no fluid is withdrawn Puncture of the bursal walls permits escape of enough exudate to relieve tension, and gradual absorption subsequently occurs with alleviation of symptoms If two needles are inserted and irrigation of the bursal sac is carried out as recommended by Smith Petersen and practiced by Darrach and others almost immediate comfort is obtained

Patterson and Darrach report 63 cases of acute subdeltoid bursitis treated by the irrigation method 57 of which obtained complete relief of symptoms, the average period of economic disability following irrigation being 4 8 days They found irrigation most successful in the following types of cases

(1) Very acute cases without history of previous attacks, (2) cases in which the calcium as seen in the *roentgenogram*, was fuzzy—not dense, round, or bone-like—and gave the appearance of not being in the tendon of the supraspinatus muscle, and (3) cases in which the acute pain was localized to one spot and did not radiate

the skin is nicked through the epidermis In like manner, a second point is infiltrated just about one quarter of an inch posterior to the greater tuberosity of the humerus on a level with the *superior facet*

Following the injection of novocaine one of the large needles is introduced through the skin incision in the anterior portion of the

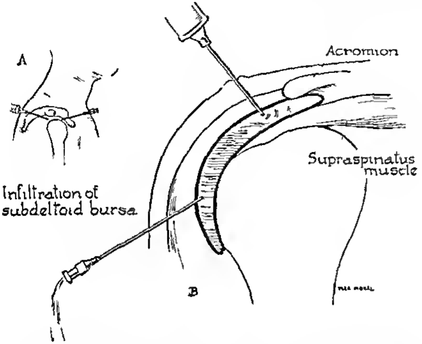

Fig 283 Technic of irrigation of acute subdeltoid bursitis as outlined by Patterson and Darrach (A) Points for inserting needles (B) irrigation of bursa with saline solution

The method of irrigation employed by Patterson and Darrach has been described by them as follows

Equipment The equipment consists of the following two 18 gauge steel needles, two and one half inches long one 20 cc syringe 60 cc of 1 per cent novocaine, a hypodermic needle one No 10 Bard Parker blade and as much saline as thought necessary (usually about 60 cc)

Technic With the patient lying on his back, the affected shoulder is prepared with iodine and alcohol Then, with the hypodermic needle and novocaine a small wheal is made in the skin over the point of maximum tenderness This point usually corresponds to a spot about one inch lateral to and on the same horizontal line as the coracoid process of the scapula Then, with the point of the scalpel,

anesthetized region The point of the needle is directed *posteriorly and upward toward the under surface of the acromial process of the scapula* The needle is then pushed deeper and after it has reached a depth of from one half to three quarters of an inch the wall of the bursa can be felt as a definite resistance provided that the syringe is held between the index finger and the thumb A quick stab places the needle point within the bursa At times, a cloudy fluid may push the plunger of the syringe back due to the increased tension in the bursa Following the placing of this anterior needle, a second one is inserted into the region just posterior to the greater tuberosity, about one fingerbreadth below the acromioclavicular joint The needle is pushed gently down to the superior facet of the greater tuberosity and actual bone is felt with the tip of the needle Then the needle is slowly

withdrawn for about one eighth of an inch and the tip of the needle is pointed in the direction of the assumed position of the tip of the anterior needle which is in the bursa After this needle has been inserted for about one half of an inch, the bursa is entered (Fig 283) Two cc of novocaine are used in each of the needles on the way down to the bursa and on going through the bursal sac

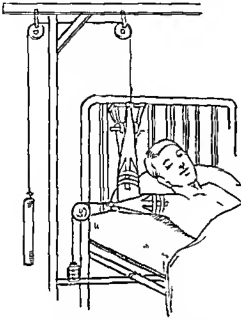

Fig 284 Arrangement of apparatus for suspension and traction of arm following irrigation or manipulation

As soon as the two needles are in place, the syringe is filled with normal salt solution and this is pushed through one needle to flow out the other A material of the consistency of toothpaste, either homogeneous in appearance or crystal like may exude At times it is so thick that it almost stops up the needle, and considerable force is required to push it through With the 20-cc syringe full of saline, it is possible at times to force the solution out the other needle for a distance of 21 inches beyond its hilt This can occur only when all the calcium has been washed out and the two needles are in perfect position At this stage, there seems to be only one advantage in having calcium show in the fluid on washing —it makes one absolutely certain that the needles are in proper position and the bursa is being washed as clean as possible

Usually as soon as one syringe of salt solution has been pushed through, the patient states that the acute pain has disappeared The amount of saline used to wash the bursa clean varies from 30 to 60 cc The needles are then withdrawn and a small sterile dressing is applied to the region of the shoulder Following this the patient can usually move the arm freely in all directions without pain At first he is reluctant to do so, because he has had so much discomfort, this is especially true in the acute cases Gentle passive manipulation can be done without harm and with actual benefit in cases of long standing Often a definite give to the shoulder can be felt

Following aspiration of an acutely inflamed bursa, it is advisable to have the patient rest in bed with the arm abducted and externally rotated This can be accomplished rather crudely by tying the wrist to the head of the bed A more comfortable method is to suspend the arm and apply moderate traction with the aid of an overhead frame and lateral traction pulley (Fig 284) During the first 24 to 48 hours sufficient sedation should be given to keep the patient well relaxed and reasonably comfortable Hot fomentations can be placed over the shoulder for 20 to 30 minutes two or three times during the second day Following the hot applications the patient should be encouraged to exercise the arm through most of the normal range of motion with the aid of weights and pulleys and slight assistance from physician or nurse No vigorous manipulations or forcible movements should be performed

When it is not possible to keep the patient in bed or keep the arm suspended and in traction, it is preferable to have the patient wear an abduction splint day and night until the process becomes quiescent The splint can be removed for daily treatment of some form of heat followed by moderate *active* exercises to increase the range of abduction and external and internal rotation

Roentgen ray therapy has been recommended by various writers for acute and chronic types of bursitis Carl Sandstrom reviewed 320 cases under the heading of

peritendinitis calcarea among which there were 75 acute cases treated by irradiation Of these he states

> In more than half of the acute cases the treatment has been finished in two to five weeks In a quarter of the cases the treatment has continued two to four months Few cases have been treated for a year

The technic used was thus described

> *In acute cases* Doses of 75 100 r every other day or every third day till the acute symptoms have subsided Thereafter if slight symptoms persist treatment is continued as in chronic cases
> *In chronic cases* Series are given of three treatments of 100 r each Between the first two or three series there is an interval of three to four weeks thereafter the intervals are two to three months
> In both acute and chronic cases the fields are varied The technic employed has been 200 kv 6 ma, 40 cm distance, 0 5 mm Cu, and 1 mm Al filter

Isadore Lattman in 1937 found that roentgen irradiation to the affected joint relieved the pain, restored the normal function, and permitted the patient to resume his normal routine more quickly than could be accomplished by any other form of treatment He found one treatment was usually all that was necessary, two or three occasionally being required He reported that 15 of the 20 cases treated were relieved of pain in from 24 to 48 hours

Samuel R Rubert, in a review of the treatment of subacromial bursitis in 288 cases at the University of Iowa, states that roentgen ray treatment has also given good results, but does not give any figures as to the numbers treated

Acute subdeltoid bursitis and other types of bursitis in the acute stage may be relieved by roentgen ray therapy, but it is doubtful whether relief can be obtained any more rapidly or effectively than by some of the other methods of treatment Most patients with acute bursitis may procure relief from the severest symptoms in 24 to 48 hours following aspiration or irrigation of the bursa and usually can return to light duty within a week or ten days but may require three to six weeks of further treatment to regain complete range of motion with freedom from pain

CHRONIC SUBDELTOID BURSITIS

Following the acute bursitis or in some cases developing as a slowly progressive subacute process there is chronic inflammation of the subdeltoid bursa with adhesions and, in many instances calcareous deposits in the bursa or in the tendinous insertions beneath These deposits appear sharply circumscribed and very dense Treatment of the chronic stage requires considerable judgment and the utmost care The measures required for relief vary from heat and massage to manipulation of the shoulder joint under anesthesia or even excision of the bursal sac and curettage of the calcareous deposits Physiotherapeutic measures alone often suffice for the chronic cases with mild symptoms that do not incapacitate the patient Aspiration or puncture of the bursa is indicated for the severer cases with considerable pain and restriction of movements of the shoulder Manipulation and operation should be reserved for patients who are seriously disabled by pain and stiffness of the shoulders

Roentgen ray Therapy Those who advocate roentgen ray therapy for the various forms of bursitis state that it is less effective in the chronic type than in the acute or subacute cases Sandstrom states, The chronic cases have been treated from two to eight months, in some cases up to a year and a half " The surgeon must, therefore, consider other measures of treatment for his chronic cases

Aspiration and Irrigation Aspiration of chronically inflamed bursae is frequently unsuccessful because of numerous adhesions, thickened walls and tenacious secretions, but may be attempted without risk of aggravating the condition and often gives relief The technic differs from that em

ployed for irrigation of acute subdeltoid bursitis Novocaine, 2 per cent solution, should be injected intradermally directly over the points of maximum tenderness With a larger needle additional novocaine solution should be injected into the muscle and wall of the bursa and when the infiltration is complete the needle should be partially withdrawn and reinserted in different directions several times in an attempt to penetrate the walls surrounding the calcareous deposits Penetration of the deposits with the needle sometimes results in their

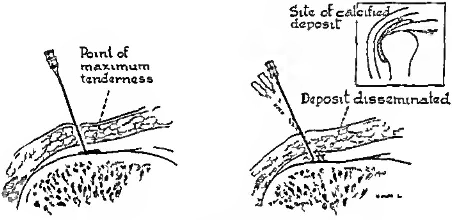

Fig 285 Puncture and dispersion of calcareous deposits in chronic subdeltoid bursitis

dispersion and absorption with relief of symptoms This procedure (Fig 285) of puncturing of the bursal walls and calcareous deposits can be combined with irrigation or carried out alone, but in either case should be followed by suitable physiotherapeutic measures

Manipulation When other measures have been consistently tried without success, and when the history, examination, and roentgenograms have definitely shown that there is no bony ankylosis of the shoulder joint, manipulation of the shoulder under general anesthesia may be performed The purpose of such manipulation is to break adhesions and stretch the contracted muscles and capsule in order to obtain a complete range of motion at the shoulder

Manipulation is not without danger, dislocations of the shoulder and fractures of the surgical neck of the humerus have occurred To prevent these accidents pressure should be made against the head and neck of the humerus in the axilla during the procedure The scapula should be held in place by an assistant while the operator grasps the flexed forearm at the elbow, makes traction on the arm, and gradually abducts it When the arm has been carried to an angle of 90° from the side of the body, the movement of external rotation should be gradually carried out and followed by complete internal rotation (Fig 286) Great force should never be used in the performance of any of the movements These various maneuvers should be carried out only once in each direction Manipulation of a shoulder with chronic bursitis produces an exacerbation that must be treated as if it were an acute bursitis Recovery in the chronic cases is usually quite slow The period of bed treatment with suspension and traction should be prolonged until the patient has acquired his complete range of active shoulder movements without pain

Physiotherapy It is often possible to omit manipulation in the chronic cases and proceed at once with bed treatment, suspension of the forearm, and traction on the

rm In the beginning the arm must be uspended in a comfortable position and raction applied (Fig 284) without attempting to correct the contractures Sedatives hould be given liberally until the patient s quite relaxed and comfortable in the apparatus Hot fomentations, radiant beat, or diathermy of low milliamperage may be

muscles may be stretched gradually, the scapular group of muscles will regain strength and the patient's morale will improve

After ten days or two weeks in bed with traction applied, these patients frequently are entirely comfortable and able to move the arm freely through an almost complete

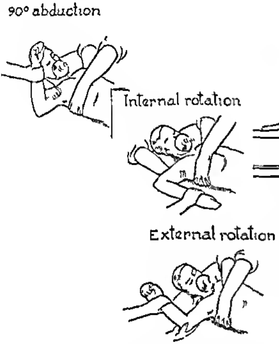

Fig 286

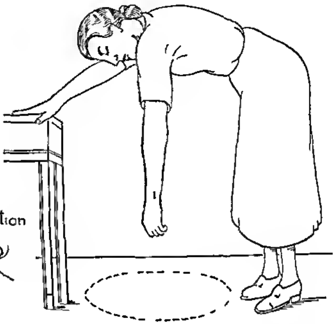

Fig 287

Fig 286 Three steps essential in procedure of manipulation for chronic subdeltoid bursitis (*Top*) Abduction to 90° with scapula held by assistant and head and neck of humerus protected by operator s hand, (*Center*) internal rotation of arm with head and neck of humerus protected, (*Bottom*) external rotation of arm with traction on humerus
Fig 287 Relaxed circumduction exercise

applied to the shoulder, and light massage may be given without disturbing the traction Following a period of two or three days of rest with application of heat and massage, the patient should be encouraged to move the arm slowly in every direction It will then be found possible to change the pulleys so as to gain more abduction and external rotation without increasing the patient s pain From day to day the angles of abduction and external rotation may thus be increased, the adhesions and contracted

range of motion They can then be allowed out of bed, and can exercise the arm by stooping forward until the arm and forearm hang directly downward, swinging the arm in a circle for several minutes a number of times during the day (Fig 287) For several nights after the patient first begins to be up and about, it is well to reattach the weights and ropes to maintain full correction

After the patient has been ambulatory a few days and can perform his stooping exer

cises freely, he may be permitted to leave the hospital and report daily for table exercises and passive stretching of the shoulder The shoulder muscles are first relaxed by the use of heat and light stroking massage, and the patient, supine on a table, is then directed to reach for the head of the table the top of his own head, the opposite shoulder, the side of the table near his axilla As his muscular strength improves weights of increasing size may be carried through the various movements obtained through manipulation or traction in order to develop sufficient strength in the weakened and atrophied muscles to enable the patient to use the arm freely and thus to avoid recurrence of adhesions and contractures

Diathermy has been accredited with hastening the absorption of deposits and improving the condition of such shoulders It is a useful method of applying heat and thus improves the circulation in the region of the joint but has no more specific action on calcium deposits than any other form of heat One should not regard it as the sole agent necessary for treatment of chronic subdeltoid bursitis At best, diathermy is only an adjunct to be combined with rest or splinting of the part, massage, active assisted movements and exercises

Operative Treatment A certain few cases with calcified deposits in the subdeltoid bursa will resist all forms of treatment and continue to manifest pain and disability Such cases may be cured by operation Symptoms usually disappear after opening of the sac and curettage of the calcareous deposits, but complete removal of the bursa is sometimes required Rubert states that of 21 such cases which were operated upon at the University Hospital, Iowa City, Iowa, ten were cured (48 per cent), five improved (24 per cent), and six unimproved (28 per cent)

Codman's technic for exposure of the subdeltoid bursa and removal of calcareous deposits as described by Campbell is fairly simple

Beginning at the tip of the acromion process the incision is carried distally three inches on the anterior aspect of the arm parallel with the fibers of the deltoid muscle The bursa which lies between the deltoid and the capsule of the shoulder joint in close proximity to the greater tuberosity of the humerus, is exposed by blunt dissection through the anterior fibers of the deltoid By rotating the shoulder medially and laterally, the limits of the bursa may be defined and the entire bursa, or the greater portion thereof, resected The tendon of the supraspinatus muscle is inspected and if infiltrated by calcareous deposits, is incised longitudinally in the direction of its fibers The material is then removed by curettage

During this operation the surgeon should bear in mind that chronic bursitis at the shoulder has been shown by Codman to be associated frequently with partial or complete rupture of the supraspinatous tendon When the bursa is opened, the articular cartilage of the humerus will be visible through the defect in the tendon if the rupture has been complete By rotating the arm internally, the retracted end of the ruptured tendon may be found, brought down from the subacromial space and sutured to the stump, or to a freshened surface on the tuberosity (See Chapters 29 and 42 for rupture of the supraspinatus) Following operation the after care of the patient should be the same as that following manipulation

Infectious Bursitis

Inflammation and swelling of various bursae may result from direct invasion of their walls by pyogenic organisms or by absorption of toxic products from a distant focus

Direct Invasion or Acute Pyogenic Bursitis Following a puncture wound or a deep laceration near a bursa, organisms which gain entrance into the walls or cavity of the bursa propagate to produce an active pyogenic inflammation with exudate of purulent character Such infections are usually of staphylococcic origin but may be mixed staphylococcic and streptococcic

During the acute stage when there is distinct redness heat and cellulitis with a tendency to spread no operative measures should be considered It is important to determine the organism responsible for the infection as early as possible The bursal contents should be aspirated and a smear and culture taken immediately Elevation of the part splinting and hot moist applications should be continued until the culture has proved the infection to be staphylococcic streptococcic a combination of the two or due to other organisms Chemotherapy should then be instituted [See Chapter 22 for choice of drug dosage etc —Ed] Adequate drainage should be instituted as soon as the process is localized preferably by crucial incision anteriorly or lateral incisions on either side with the insertion of vaseline gauze strips into the bursal cavity Splinting and hot applications should be continued postoperatively until the discharge has ceased and there is a granulating surface At this time gradually increasing movement of the joint may be permitted and eventually the patient is encouraged to employ full motion and weight bearing

Chronic Infectious Processes TUBERCULOSIS Tuberculosis *may occur in various* bursae as an extension from a focus in the bone or adjacent joints In addition it may appear as a separate infection in the trochanteric bursa and has also been noted in the pretibial bursa If the infection is strictly limited to the bursa it is sometimes possible to excise it *in toto* with subsequent permanent healing This has been accomplished in cases of infrapatellar bursitis but rarely can be accomplished in the trochanteric bursa

SYPHILIS Various bursae may demonstrate *syphilitic involvement the prepatellar* bursa being most frequently affected The histories of such cases suggest that there existed a chronic bursitis which later becomes syphilitic in nature Antisyphilitic treatment together with elimination of all irritation and trauma will effect a cure if lues is the etiologic factor

Bursitis Secondary to Remote Foci of Infection The most striking example of this is seen in the bursitis that develops beneath the heel designated as calcaneal or subcalcaneal bursitis It is usually found in people who have acute or chronic gonorrheal urethritis prostatitis or vesiculitis and who are also overweight or constantly on their feet Less frequently the same mechanical factors combined with a tonsillar abscess or apical abscesses of the teeth will cause calcaneal bursitis

The injection of novocaine or normal saline into and about the affected bursa has relieved the tenderness at the heel in some cases The materials injected probably have less to do with the subsidence of symptoms than the puncturing of the distended bursal sac and adjacent indurated tissues In any case it may be helpful to inject the skin over the inner side of the heel with 2 per cent novocaine solution then to introduce a larger needle and carry the injection down to the bursal sac When sufficient time has elapsed for the novocaine to take effect the same needle should be passed through the resistant bursal wall and plantar fascia and partially withdrawn and reinserted several times Rest elevation of the part, and the use of *hot fomentations* should be advised for 24 to 48 hours after this procedure has been carried out When the tenderness has diminished and the patient resumes weight bearing attention should be directed toward the footwear The shoes should be well fitted the entire heel raised one fourth to one half inch to throw more weight to the forefoot and a soft sponge rubber pad placed beneath the heel in the shoe (Fig 288 A) By means of a special arch support of metal or sponge rubber with a cupped heel and high instep most of the transmitted weight of the body should be taken on the instep and ball of the foot rather than on the center of the heel

Accompanying calcaneal bursitis there

frequently develops a bony spur or exostosis projecting anteriorly from the ridge between the medial processes of the tubercle of the calcaneus into the plantar fascia as revealed in a lateral roentgenogram of the heel Conservative measures such as have been outlined are sufficient for relief of many of the thickened bursae but some require removal of the exostosis The operation should be performed through an incision extending for about two inches along the inner side of the heel parallel to its plantar surface Through this incision the medial process of the tubercle of the calcaneus may be exposed together with the ridge from which the plantar muscles and fascia take origin When the attachments of the fascia and muscles have been stripped away from the bony ridge, the exostosis may be revealed and can then be completely removed with an osteotome Bleeding points should be tied off, the wound closed with

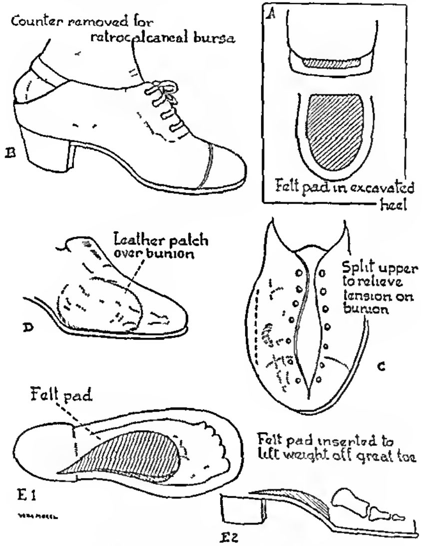

FIG 288 Various shoe corrections used in treatment of bursitis occurring in region of foot and ankle

interrupted sutures, and a pad bound under the sole of the foot with an elastic bandage The foot should be kept elevated for a period of from 48 to 72 hours The patient can then begin to walk about with the aid of a crutch bearing a little weight on the toes of the foot Sutures may be removed at the end of ten days or two weeks Two or three days later a shoe with a pad under the heel may be supplied

Bursitis Accompanying Gout

Gouty deposits are occasionally found in bursae about the great toe joint and rarely at the shoulder, elbow, and knee These chalky deposits may be mistaken for calcium but will usually disappear in response to rest, a purin free diet and the administration of some preparation of colchicum

Bursitis in Special Regions of Body

Foot and Ankle

Of the numerous bursae located in this region those most frequently involved are the retrocalcaneal, which lies between the tendo achillis and the tuberosity of the os calcis the Achilles bursa lying between the skin and the insertion of the tendo achillis and the calcaneal bursa, lying beneath the tuberosity of the calcaneus In addition to these, adventitious bursae may develop over the first metatarsophalangeal joint in connection with the formation of bunions Others, known as tailor s bursae develop over the external malleoli from the pressure over those points caused by the cross-legged sitting position in which tailors usually work Some patients, particularly those with clubfoot exhibit large adventitious bursae over the outer side of the cuboid and proximal end of the fifth metatarsal

Retrocalcaneal Bursitis Inflammation of this bursa is usually caused by wearing short or ill fitting shoes, the counters of which make undue pressure over the posterior aspect of the calcaneus at the insertion of the tendo achillis If there is some irregularity of this surface of the calcaneus, the bursa is much more likely to become inflamed, and under such conditions treatment must be directed to the bone itself as well as to the bursa In the early acute case, rest and the use of hot fomentations cutting away the counter of the shoe posteriorly (Fig 288 B) and elevation of the heel in the shoe by placing a pad of felt or sponge rubber one fourth to one half inch thick beneath the heel will cause subsidence of the swelling and tenderness The altered shoes should be worn for two to four weeks until all tenderness and most of the swelling have disappeared, after which properly fitted shoes should be provided If, in spite of these precautions the bursa recurs, it should then be excised together with any bony enlargement or small exostosis which may be present

Achillobursitis Achillobursitis is brought about in much the same manner as retrocalcaneal bursitis and the treatment of the condition is precisely the same Isadore Zadek points out that simple excision of this bursa is no more likely to effect a cure than excision of the bursa over the first metatarsophalangeal joint could be expected to give complete relief for bunion in the presence of hallux valgus deformity He, therefore, recommends the removal of a V shaped wedge from the superior surface of the tuberosity of the os calcis with closure of this opening in the bone by forcing the posterior segment forward, thus reducing the posteriorly projecting bony prominence to a point where the shoe counters cannot produce undue pressure

Calcaneal Bursitis This bursa is most frequently associated with a remote infectious process and has been discussed under infectious bursitis

Bunion Associated with hallux valgus an exostosis usually is seen on the medial aspect of the head of the first metatarsal bone Constant friction and pressure of the shoe over the exostosis then results in the formation of an adventitious bursa on the medial side beneath the skin The treatment of

acute bursitis associated with bunions consists of rest and elevation of the feet and the application of hot fomentations until the acute tenderness and swelling have subsided Soaking the feet in hot solutions of hypertonic saline is gratifying to many patients and is easier managed in the home than fomentations On resuming the wearing of shoes all pressure over the great toe joint should be removed This may be accomplished by splitting the shoe down the midline of the upper and toe cap or by cutting out the inner side of the upper opposite the joint (Fig 288 C) When the upper has been cut out on the inner side it can be repaired by a patch with convex contours large enough to accommodate the enlarged joint (Fig 288 D) The plantar surface of the great toe joint should be protected by a felt or sponge rubber pad one-fourth to one half inch thick on the inner side and beveled to no thickness on the outer side and beneath the metatarsal heads (Fig 288 E 1 and E 2) Eventually a shoe of ample width with a straight inner border may be supplied

Chronic bursitis associated with marked hallux valgus and deformity of the forefoot is best treated by one of the operative procedures recommended for treatment of bunion All of these procedures include attention to and disposition of the bursa In addition it is necessary to remove the exostosis correct the alignment of the first metatarsal and narrow the metatarsal portion of the foot [See Chapter 5 —Ed]

Other Adventitious Bursae The tailor s bursa over the external malleolus is usually a chronic condition best treated by removal The large bursae which develop as a result of weight bearing over the outer side of the foot in clubfoot deformities require no special treatment if the deformity is corrected and the weight bearing transferred to the sole of the foot Bursae over the plantar surface of the metatarsal heads are best treated by the insertion of well adjusted metatarsal pads in corrective shoes Occasionally these are quite acute and demand some days of rest elevation and hot applications as preliminary treatment

KNEE

The bursae in this region which are most frequently involved are the prepatellar which lies between the skin and patella the pretibial lying between the patellar tendon and the tubercle of the tibia and the superficial pretibial lying directly between the tibial tubercle and the skin Any or all of these may originate from traumatism or infection with a resulting acute or chronic bursitis Treatment of acute involvements of the bursae lying anterior to the joint proper consists of aspiration of the distended bursa followed by the use of a splint back of the knee and a pressure pad bound in place over the bursa with an elastic bandage Hot compresses may be applied if there is considerable inflammation around the bursa

If there is appreciable cellulitis redness increased heat and some fever indicating a purulent involvement the part should be elevated and kept at rest hot applications used and chemotherapy as outlined in Chapter 22 instituted until the process is well localized Drainage should then be instituted and splinting continued until the healing is progressing satisfactorily

Chronic involvement of these various bursae in the anterior region of the knee may be the result of repeated traumatism or of low grade infection Syphilitic and tuberculous involvements are always to be considered and these possibilities should be eliminated before operative treatment of the bursae is undertaken Chronic traumatic bursae should be excised completely The technic of excision should be similar to that described in the earlier part of this chapter for chronic traumatic bursitis

Popliteal Bursae Numerous bursae are found in the posterior knee region most of which are not constantly present and are seldom enlarged The one most commonly affected and producing symptoms is the

bursa beneath the medial head of the gastrocnemius and the tendon of the semimembranosus, and is known as a popliteal cyst or Baker's cyst. Palliative treatment is usually ineffective in this type of chronic bursitis. Operative removal, preferably through a transverse incision, is the procedure of choice.

There is also a bursa between the tendon of the biceps, the semimembranosus and semitendinosus known as the bursa anserina. When this is chronically involved it should be excised in the same manner as outlined for the removal of Baker's cyst.

These posterior bursae may communicate with the knee joint, and are sometimes quite extensive, requiring tedious dissection for complete removal. Meticulous technic should therefore be used in aspiration for diagnosis, and the excision is subject to all the precautions alluded to under excision of ganglion.

HIP

Of the numerous bursae described in this region, only three have become involved with any frequency: (1) The trochanteric bursa, lying between the tendinous attachment of the gluteus maximus and the lateral surface of the great trochanter, (2) the ischiogluteal, beneath the gluteal muscle overlying the tuberosity of the ischium, and (3) the iliopectineal, between the iliopsoas muscle and the pelvis.

Trochanteric Bursitis. Acute trochanteric bursitis of traumatic origin usually subsides promptly with rest, hot applications, and perhaps aspiration. Subacute or chronic cases occasionally show calcified deposits in this region, many of which respond well to irradiation. Acute suppurative involvement of this bursa requires incision along the posterior margin of the great trochanter with due care to avoid the sciatic nerve. Chronic suppurative involvement of this bursa should suggest tuberculosis. Infection of this bursa by tuberculosis without demonstrable lesions in the hip joint or in the trochanter has been observed by several writers. However, the great majority of these cases have, or later show, involvement of the greater trochanter or of the hip joint itself. It is well to keep this in mind in giving a prognosis and in the examination of the patient.

In these cases aspiration, rest, and pressure combined with the usual general measures of treatment for tuberculosis have been recommended and tried. Those who have attempted excision have found it to be not only formidable, but also unsuccessful.

Ischiogluteal Bursitis. This type of bursitis occurs in patients whose occupations require them to sit constantly and at the same time to move the trunk frequently. The constant irritation over this bursa causes a chronic thickening and increase of fluid until it becomes enlarged. The acute and subacute stages of this trouble may be cured simply by a change of occupation, but when it has progressed to the chronic stage excision will be required.

Iliopectineal Bursitis. Because iliopectineal bursitis is usually associated with and secondary to acute inflammatory conditions in the hip joint, the treatment, which consists of incision and drainage, is limited to the acute suppurative type. When the incision is made, one should be prepared to extend it into the hip joint if the bursa is found to be communicating with a suppurative focus in the joint.

ELBOW

Bursae in the region of the elbow which most frequently become involved are the olecranon and the radiohumeral.

Olecranon Bursitis. This develops as a result of repeated trauma or rarely as infection secondary to abrasions or a punctured wound. The traumatic types in the early stages respond to aspiration, rest, and splinting with a small pressure pad over the enlarged bursa. [The acutely infected bursa is probably best treated by excision in conjunction with chemotherapy by mouth and

locally, the wound being packed loosely open and allowed to granulate Incision and drainage is unsatisfactory and in most instances has to be followed by excision — Ed] The chronic recurrent type requires excision through a transverse incision, and, when there is considerable enlargement, removal of a section of skin in order to thoroughly collapse the cavity

Radiohumeral bursitis—also designated as 'tennis elbow, epicondylitis and epicondylalgia—is the result of slight traumatization in the region of the radiohumeral joint following excessive use of the arm in extension and supination

In the acute stage support of the arm in a sling with a cock up splint on the wrist and forearm together with applications of heat and massage for a period of ten days or two weeks may alleviate the pain More prompt relief is probably attained by immobilization if preceded by puncture of the bursa or injection with novocaine

If the bursitis has persisted for several weeks or has recurred several times, one must choose between excision or a manipulative procedure such as that described by Mills The latter consists of flexing the fingers and wrists, fully pronating the forearm, with pressure of the thumb over the bursa, the forearm can then be forcibly extended, thus rupturing the bursa or lacerating the fibers in the vicinity of it in such a manner as to relieve the trouble In long standing cases the use of an anesthetic is advisable

Operative Removal of Radiohumeral Bursitis The radiohumeral bursa lies between the conjoined tendon and the radiohumeral joint Osgood recommends exposure through an oblique incision one and a half inches long from above the external epicondyle well down over the head of the radius The conjoined tendon is defined its fibers carefully split to uncover the bursa if present Hohman advises exposure of the epicondyle, transverse division of the origins of the conjoined tendons on the anterior surface, inspection of the area beneath, and removal of the bursa when present Watson Jones believes that the operation achieves the same purpose as the manipulation— it releases the strain on an incomplete tear, allows repair of the tendon with slight lengthening and therefore removes the localized traction of a strong muscle from painful periosteum '

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SECTION FOUR

NEW GROWTHS

12

Tumors of Bones and Joints

A TREATMENT OF BONE TUMORS

BRADLEY L. COLEY, M D

Before considering the various methods of treatment of the complex group of bone tumors, it is essential to have as clear an understanding as is possible of the various types that compose this group We know that some of the tumors are benign, some are malignant and others that are benign at the start may, under certain circumstances, become malignant

While a number of classifications of bone

CLASSIFICATION OF BONE TUMORS*

	Malignant	*Benign*
1 Osteogenic series	1 Medullary and subperiosteal 2 Telangiectatic 3 Sclerosing 4 Periosteal 5 Fibrosarcoma (a) Medullary (b) Periosteal 6 Parosteal, capsular	1 Exostosis 2 Osteoma
2 Chondroma series	1 Chondrosarcoma 2 Myxosarcoma	1 Chondroma
3 Giant-cell tumor series	1 Malignant	1 Epiphyseal giant cell tumor
4 Angioma series	1 Angio-endothelioma 2 Diffuse endothelioma	1 Cavernous angioma 2 Plexiform angioma
5 Myeloma series	1 Plasma cell 2 Myelocytoma 3 Erythroblastoma 4 Lymphocytoma	
6 Reticulum-cell lymphosarcoma		
7 Liposarcoma		

* As revised in 1939 by the Bone Sarcoma Registry of the American College of Surgeons.

tumors have been offered, the following one recently revised and approved by the committee of the Bone Sarcoma Registry of the American College of Surgeons seems to have most to recommend it, and it is hoped that eventually it will become the universally accepted one

BENIGN TUMORS OF BONE

Exostosis, Osteoma

Single exostoses that are causing no symptoms may not call for any treatment They should be kept under observation, both clinical and roentgenographic, since occasional cases may undergo transformation into osteogenic sarcoma Those causing pain or interference with function may be removed by simple surgical excision which should be complete, and should include the underlying cortex as well as the base of the exostoses

Multiple exostoses occur as a distinct clinical entity which is termed *familial deforming chondrodysplasia* In addition to the actual exostoses, some of these patients show skeletal deformities with bending of the bones and irregular widening of the metaphyseal region In these cases it is our practice to keep the patient under observation, to await full bone growth, and to operate only when symptoms of nerve pressure, vascular pressure, or deformity are present, then complete excision is recommended [For other factors in this disease, see Chapter 3 —Ed]

Chondroma

This common benign tumor is often grouped with osteoma In fact, cartilaginous and osseous tissue often occur together in the osteochondromatus process referred to as *exostosis* The pure chondroma is more often a central tumor, hence the older term *enchondroma*

While these tumors are usually seen in the small bones of the extremities, particularly in the phalanges and metacarpals and metatarsals, they may occasionally occur in the major long bones Multiple lesions are relatively rare

These tumors may undergo a change to chondromyxosarcoma This is far more apt to occur in the larger lesions situated in the major long bones, in the ribs or sternum, than it is in those of the smaller bones In the phalanges such a development is exceptionally rare It may occur in only one of the lesions when the patient has multiple growths

Although complete extirpation by curettage has been found to be successful, recurrences are common and bespeak a failure on the part of the surgeon to remove every particle of the diseased tissue The importance of a thorough cauterization of the curetted cavity with zinc chloride cannot be too strongly emphasized (For more details see Surgical Treatment of Giant cell Tumor, below) Where feasible, resection may be the method of choice Roentgen therapy has not been found to be successful in most cases of chondroma It is hardly rational to expect radioresistant tissue to respond to light dosage and heavy dosage for benign lesions of this type is scarcely justifiable

In brief, if operation is chosen, it should envisage a thorough and wide removal of the diseased tissue by surgery and cautery, and closure of the wound without drainage

Giant cell Tumor

This tumor is usually confined to the ends of the long bones Only infrequently is it found in the flat bones, such as the pelvis or scapula The lower femur and the upper tibia account for 80 per cent of all cases A variant form is the so-called *epiphyseal chondromatous giant cell tumor* described by Codman, occurring most frequently in the upper humerus

The two methods of treatment widely used are (1) radiation by means of roentgen ray, and (2) surgery While many authorities have advanced the claims of each we believe that for accessible lesions, par

ticularly those in the femur and tibia a thorough curettage followed by cauterization and primary wound closure is the method of choice For inaccessible lesions e g those lesions in the upper femur, pelvis or spine radiation has been found to be preferable

Surgical Treatment of Giant cell Tumor *Preoperative* The skin preparation is an important step and should be carried out carefully Provision should be made for a transfusion to be administered immediately after the operation in the event of unexpected loss of blood Under general anesthesia a tourniquet is applied and the skin incised over the tumor bearing portion of the bone The incision should be so placed as to avoid the neighboring joint (Fig 289) and give access to the bone with a minimal amount of damage to the overlying soft parts This is done where possible by splitting the muscles rather than dividing them The periosteum is exposed incised and stripped back from the cortex A rectangular window is then made by an osteotome or twin bladed motor saw (Fig 290) The window is then enlarged with a rongeur (Fig 291) until a thorough curettage of the tumor filled cavity can be performed under direct vision aided by palpation

At this stage the Cameron light is useful No unnecessary sacrifice of cortical bone should be made A curette with an angular handle (Fig 292) helps one to reach the roof of the cavity and to completely remove all particles of tumor tissue and cancellous bone The cavity is repeatedly flooded with Dakin s solution or normal saline solution *When the surface of the* bone cavity is clean the interior is thoroughly swabbed out with a saturated solution of zinc chloride (or if this is not available with pure phenol followed by alcohol) which is allowed to remain in contact with the bone for about one minute care being taken to protect the soft parts from contact with the escharotic solution which is flushed away by repeated flooding of the cavity with Dakin s solution

The periosteum muscle, fascia and skin are closed in separate layers with interrupted sutures without drainage Since the bone shell usually possesses sufficient regenerative power to restore continuity we do not advocate stuffing the cavity with

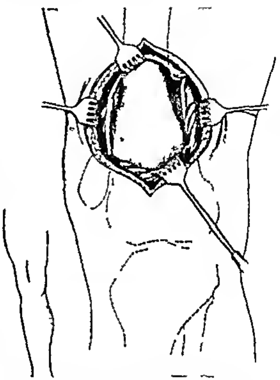
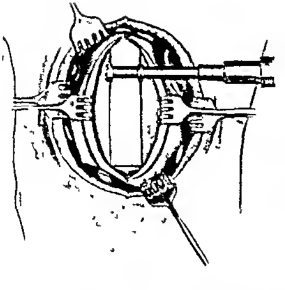


Fig 289 Shows exposure of involved portion of femur with retraction of rather than divis on of muscles (Courtesy Coley and Higinbotham Ann Surg 103 No 5)

bone chips although it is the practice of many surgeons [Many men feel that the insertion of long curling chips taken from adjacent bone or from the tibia or ilium is the safer procedure if the cavity left after curettage is of any size If the biopsy of the tumor material taken at operation shows a profusion of giant cells recurrence is particularly apt to take place and more than ordinary thoroughness in removal and curettage and the use of bone chips is indicated in these cases —Ed] Where the tumor is



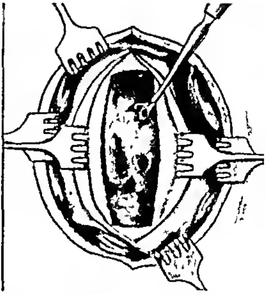


FIG 290 (*Left*) Shows periosteum divided and retracted and window of cortical bone outlined by motor saw. This step can be done with an osteotome and, where the shell is very thin, sometimes by knife or heavy scissors.

FIG 291. (*Right*) Shows window enlarged by rongeur and curettage of tumor tissue being carried out.

(Courtesy, Coley and Higinbotham: Ann Surg, 103: No. 5)

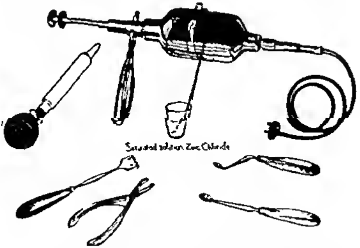


FIG. 292. Instruments useful in surgical treatment of giant-cell tumor. (Courtesy, Coley and Higinbotham: Ann Surg, 103: No 5)

extensive, and the resulting cavity large, a tibial bone transplant is often an aid in securing regeneration of bone Fine silk is used for the skin care being taken to maintain accurate approximation The tourniquet is removed and a bulky gauze dressing with sterile sheet wadding and a snug flannel pressure bandage is applied Plaster encasements or splints are used where indicated

For the first 72 hours after operation the part is kept elevated When the skin sutures are removed the wound is redressed still maintaining moderate pressure as at the initial dressing Great care is taken to prevent a pathologic fracture In lesions of weight bearing bones the use of caliper splints is indicated until roentgenographic examination shows adequate bone regeneration In some cases the slight degree of involvement permits a very brief period of restraint in others some months are required for the bone defect to be filled up sufficiently to permit full function with safety

Radiation Therapy Where experience in the surgical treatment of this condition is lacking roentgen therapy is the safer procedure This form of irradiation, we believe has many advantages over the radium pack For a tumor occupying a relatively superficial position—around the knee where the majority occur—a voltage of from 125 to 150 kilovolts with a 4 Mm aluminum filter, at a target skin distance of from 25 to 30 cm is preferable Moderately heavy doses are given with the above factors a suberythema or threshold dose (approximately 500 roentgen units depending on the size of the port) being administered at a single treatment The ports are treated at intervals of from four to seven days A cycle might consist of four exposures two to each port

It should be borne in mind that these doses are only rough approximations Due to difference in the size and depth of the tumors and the marked variations in radiosensitivity, there can be no standard method or dosage laid down in the roentgen therapy of giant cell tumors

As a rule, regeneration and healing require a longer period under radiation than under surgery, so that in the former group the supporting casts and braces must be worn over a longer period of time

Cavernous Angioma, Plexiform Angioma

These are exceedingly rare conditions of bone They are so seldom encountered that their treatment has never been standardized Radiation might control extension of the process Surgery would require removal of the diseased area and this might entail either segmental resection and massive bone graft or amputation

Bone Cyst

The similarity of this condition to giant cell tumor has been frequently described therefore while it tends to be a regressive process rather than a progressive one the treatment is similar Conservative surgery is the method of choice of many authorities including Von Haberer, Hoffmeister, Tavernier Mouchet Dujarier, Heitz Bayer, Ombredonne Bloodgood Sisk and Painter According to Sisk

> In the treatment of osteitis fibrosa cystica the greatest economy of time is served by conservative surgery, at the time the lesion is discovered The uniform success obtained by surgery with a comparatively short convalescence period argues against long periods of watchful waiting

If a pathologic fracture has occurred in a bone cyst not previously recognized, manipulation to obtain satisfactory position, followed by immobilization, will result in healing of the fracture, and sometimes the cyst also will heal without further interference However, the latter may persist, and later re fracture may take place [The popular conception is that fracture through a bone cyst results in healing of

the cyst spontaneously in the great majority of cases This is not so Careful studies on a considerable number of cases have shown that only about 18 per cent of bone cysts through which fracture has occurred disappear spontaneously Eighty two per cent either remain unaffected, or actually extend after the lesion although the fracture almost invariably heals without difficulty — Ed]

We recommend the following operation exposure of the bone at the area involved removal of a rectangular window large enough to give access to the entire cavity a thorough curettage of the contents down to intact cortical bone The cavity may then be swabbed out with zinc chloride, or carbolic followed by alcohol and flushed with saline solution or Dakin s solution The rectangular fragment previously removed is then replaced in the cavity and wedged firmly into the medullary cavity where it serves as a graft (some surgeons prefer to fill the cavity with bone chips) The wound is then carefully closed in layers without drainage, and a voluminous, snug dressing applied with firm pressure Support by splints or plaster casing is used if required to prevent a subsequent fracture from occurring

A prompt filling in of the cavity with bone is the expected result of such treatment Recurrence is rare if the procedure is carefully carried out

Radiation Therapy The possibility of damage to adjacent growth centers following roentgen ray exposure of nearby cystic areas makes some clinicians hesitant about employing this method In some of our cases it has produced excellent results in causing a filling in of the cyst Our preference, however, is for surgery (for accessible lesions), which we believe gives more certain results

Prognosis The prognosis for a satisfactory result both functional and anatomic, is good There should be no danger to life or limb nor any occasion for a mutilating type of operation, and there should be no mortality The fracture seldom results in marked deformity and usually heals promptly When the cystic area is extensive and the fracture compresses this area, some shortening may result although it s minimized by the natural tendency of children spontaneously to overcome such shortening Therefore, with the exception of lesions of the lower extremity, this is of little importance Neglected cases may develop a bending deformity when unprotected weight bearing is permitted over a considerable period of time

Results in a Series of 26 Cases of Bone Cyst

Treatment Employed	*Results*			
	Good	*Fair*	*Poor*	*Not Traced*
1 No treatment	0	0	0	1
2 Treatment of fracture only	4	0	0	0
3 Curettage alone	5	0	0	0
4 Curettage after fracture	5	0	0	0
5 Curettage plus graft	2	1	0	0
6 Curettage plus radiation	1	0	0	0
7 Treatment of fracture plus radiation	2	0	0	0
8 Radiation alone	2	1	0	1
9 Radiation—later fracture—malunion requiring osteotomy	0	1	0	0
Totals	21	3	0	2

MALIGNANT TUMORS OF BONE

Osteogenic Sarcoma

Special emphasis should he laid upon the necessity of an early diagnosis in this type of highly malignant tumor, since prompt treatment is of the utmost importance In establishing the diagnosis one should weigh carefully all the factors involved, i e, the patient s history, the clinical evidence, the roentgenographic findings, and the histo logic appearance

Since a microscopic examination is es sential tissue must be available To obtain this, an aspiration hiopsy is usually ade quate Before undertaking this step how ever a careful study of the roentgenograms should be made since some osteogenic tumors are of medullary origin and, there fore are not approachahle with an as pirating needle through the intact normal cortical bone

Technic of Aspiration Biopsy The selection of the proper site for aspiration is more difficult in deeply situated tumors than in those on the surface Aside from the anatomic relationships, central tumors are frequently encountered in which the hony shell may or may not be still intact If roentgenograms show that it is broken at any point, it is advantageous to aspirate there

Novocaine infiltration of the skin and soft tissues is advisable hefore passing through to the deeply seated bone tumors Adequate infiltration renders the procedure practically free from pain A brief gas oxygen anesthetic can be used if conditions warrant It may be necessary in young or very nervous subjects

There are several possible explanations for the failure to obtain cells Some fihrous tumors, such as the osteogenic fibrosarcoma, may, by their texture, present great difficulty in aspiration The technic may be faulty It seems certain that practice is necessary in order to obtain a high percentage of positive results There are several methods of utilizing the material ohtained If there is hut a minute amount of tissue, the smear is the only suitable one In case large plugs of tissue in cylindrical shape are expelled from the needle, as may happen uoder ideal conditions, a portion of the tissue may he hardened in formalin and paraffin sections made in the usual manoer Many bone cases are extremely vascular and often yield what appears to be only hlood If the hlood clot is hardened aod sectioned by the paraffin method, tumor cells are frequently demonstrable The syringeful of hlood may he expelled through a few thicknesses of gauze which filters out floating particles of tumor These may tben be transferred to glass slides and smeared or, if of sufficient bulk, may be bardened and sectioned In the majority of our cases, two or more of these methods are used as checks oo one another

Technic The special paraphernalia required is an ordinary 18 gauge needle 5 to 10 cm in length (which should he new and sharp) and a 20 cc Record syringe For the preservation of the specimen, glass slides and a specimen hottle with 10 per cent formalio are needed

The skin at the site of the intended puncture is painted with iodine and a small area of skin infiltrated with 1 per cent novocaine With a histoury pointed scalpel (No 11 Bard Parker blade) a stab wound is made through the skin with the instrument held at right angles to the skin surface This puncture of the skin facilitates insertion of the needle An 18 gauge needle attached to a tightly fitting Record syringe is then inserted and advanced slowly through the superficial tissues until the point is felt to enter the suspected neoplastic mass Guided by palpation with the disengaged haod, it is striking how readily a difference in consistency of the tissues can he felt as the needle enters a mass of neoplasm When the point of the needle is felt to enter the tumor, the piston of the syringe is partly withdrawn so as to produce a vacuum and the needle slowly advanced 1 to 3 cm, depending on the anatomy and size of the tumor Maintaining the vacuum, the needle is then withdrawn to the same distance and advanced again This manipulation may he repeated two or three times at the discretion of the operator, care

being taken to maintain the vacuum when the needle is advanced or partly withdrawn As piration with the needle at rest is not sufficient to draw tissue into the needle in most cases By advancing the needle and aspirating simul taneously, a plug of tissue is both forced and drawn into the needle Maintaining suction during partial withdrawal detaches the plug of tissue already within the needle We have found this detail to be very essential Before the needle is completely withdrawn from the tissue the piston must be slowly released until

FIG 293 (*Left*) Osteogenic sarcoma with narrow attachment to femur Prob ably malignant transformation of osteo chondroma (Bone Sarc Reg No 2249) (Apr 2, 1937)

FIG 294 (*Right*) Same case nine months after resection of tumor and its base No evidence of recurrence three and one-half years after operation

the pressure in the needle is equalized, or better still, the syringe detached and the needle withdrawn separately, otherwise the aspirated material will be suddenly drawn and splashed over the interior of the syringe, mak ing its collection difficult While the needle is being advanced and withdrawn under negative pressure, a small quantity of blood mixed with fragments of tissue may enter the syringe, or a solid cylindrical mass of tissue may appear In other cases, especially in the firmer masses, the syringe apparently remains empty, but after withdrawal the needle is usually found to contain a plug of tissue

After complete withdrawal of the apparatus, the syringe is detached from the needle, filled with air, attached, and the contents of the needle slowly and carefully expelled on a glass slide A small fragment of tissue should be left on the slide for smearing and the re mainder placed in the specimen bottle for fixation and staining by regular methods If the needle is empty, small masses of tissue can almost always be found mixed with blood in the syringe, and these should, if necessary, be very carefully searched for One or two of the e small masses can readily be fished out upon a glass slide for smearing and immediate staining In any case where the syringe con tains blood or any tissue, formalin from the specimen bottle is poured into the open barrel of the syringe, agitated and returned to the specimen bottle

Surgical Biopsy This procedure some times condemned, is, nevertheless, occa sionally necessary to establish the diagnosis If done under proper conditions in selected cases, it has not seemed objectionable The wound should invariably be carefully closed in layers and every effort made to insure primary wound healing Packing or drain age should never be employed, as infection and fungation are prone to follow The biopsy should include characteristic tumor tissue, if this is lacking an incorrect diag nosis will result The procedure should be carried out preferably by the surgeon who is to have charge of the subsequent man agement of the case Where aspiration biopsy has been tried unsuccessfully, re sort must be had to surgical biopsy before undertaking any such radical measure as amputation It is more difficult for the pathologist to render a definite diagnosis on material obtained by aspiration biopsy than on blocks of tissue taken by surgical biopsy Unless such experienced pathologic assistance is available, the aspiration biopsy had better not be attempted [Many men believe that biopsies on suspected malig nancies of the extremities should be done under a single or double tourniquet The utmost gentleness in handling the tissues should be exercised to avoid the possibility of initiating metastases It is also held that, if an operative biopsy is to be done, it should be done with the surgeon, the pa tient, and his family prepared to have the

indicated procedure carried out at the time of biopsy if the specimen shows evidence of unquestioned malignancy on gross or frozen section examination —Ed]

ATYPICAL OSTEOGENIC SARCOMAS

Resort to amputation may be avoided in exceptional cases by attempting a wide resection or excision of an involved bone or its tumor bearing portion Experience and judgment are necessary for the selection of these cases The indications involve the presence of a low grade fibrosarcoma or chondrosarcoma which, by its location, lends itself to resection or excision Some of these cases seem to have originated in a process closely akin to myositis ossificans, others originate in a pre-existing chondroma or osteochondroma That few of the reported cases treated by such conservative procedures have remained well for five years or more should not discourage a continued attempt to discriminate between those suitable for such methods and those requiring an immediate amputation

Amputation INDICATIONS Amputation for osteogenic sarcoma should never be undertaken until the diagnosis has been definitely established While roentgenographic evidence is of great importance there are other factors to be considered, and, in the final analysis, the microscopic evidence is paramount Further corroboration of the diagnosis is afforded by chemical studies of the blood, i e, serum phosphatase These diagnostic procedures supplement a thorough clinical investigation, a carefully elicited history, and a complete physical examination, the value of which is not to be underestimated *For example,*

FIG 295 FIG 296 FIG 297

FIG 295 Borderline chondromyxosarcoma, recurrent after three attempts at local extirpation (Bone Sarc Reg No 2083) (Feb 26, 1935)

FIG 296 Same case after segmental resection of middle third of humerus and substitution of massive tibial transplant (Feb 23, 1937)

FIG 297 Same case, 18 months later Patient still free of disease, 3¾ years after resection

palpation of the groin or axilla may reveal extension to the major veins in which event amputation would be futile This extension explains some of the prompt stump recurrences that occasionally are encountered During these preliminary investigations, the part should be kept at rest If the sarcoma is located in the lower extremity, crutches should be used if it is in the upper extremity a sling or a splint should be worn


Fig 298 (*Left*) Osteogenic sarcoma of proximal phalanx of fifth finger—an exceedingly rare location for this disease (Bone Sarc Reg No 2246) (Feb 16 1937)

Fig 299 (*Right*) Same case one year after resection of part of hand Patient well 2¾ years postoperative

Amputation may be indicated in the hope of a permanent cure or as a purely palliative measure for the relief of pain, to prevent fungation and infection or to rid the patient of a cumbersome, useless extremity In such cases the presence of demonstrable metastases is not a bar to amputation However, when palliation only is contemplated, the life expectancy with and without amputation must be considered If this is regarded as short amputation had best be abandoned The psychologic effect of relieving pain and removing the offending member frequently justifies the procedure

Level of Amputation Since in certain rapidly growing sarcomas there is an extension of the disease up the marrow cavity far beyond any roentgenographic indication, the rule that *amputation should never be performed through the affected bone* is generally accepted as a wise one However when the lesion originates in the lower femur, and when roentgenographic and clinical examination indicate that a safe margin is to be afforded by amputating through the proximal fourth of the femur or even just distal to the lesser trochanter then this site is greatly to be preferred to a hip joint disarticulation The latter affords a most unsatisfactory opportunity for the fitting of an artificial limb and is a more shocking procedure

In certain selected cases of low grade sarcoma of the scapula one may avoid a mutilating amputation of the upper arm by performing a total or subtotal disarticulation of the scapula (Figs 300 301)

Preoperative Measures A roentgenogram of the lungs should be taken to exclude demonstrable metastases Provision should be made for a transfusion during or after the operation Skin preparation should be carefully carried out we prefer a 48 hour preparation The parts are covered with sterile dressings

Anesthesia In most cases nitrous oxide or ethylene with the addition of ether is entirely satisfactory Avertin is an excellent basal anesthetic particularly in young children or in nervous subjects Cyclopropane is ideal for the elderly or frail patient Because of the psychic disturbance associated with severance of a limb spinal anesthesia is used less frequently than before

Technical Considerations of Amputation Since amputation is considered in another chapter, only those details that seem particularly worthy of emphasis will be considered here [See Section Six, Chapters 19, 20 and 21 —Ed]

Protection of the wound edges with sterile towels is to be recommended Blood loss

should be scrupulously avoided by the use of a tourniquet * The latter is prevented from slipping on the thigh or upper arm by the use of Wyeth pins The tourniquet is quickly applied and quickly released In our experience, it has never slipped, it has controlled hemorrhage without exception, and has unquestionably shortened the operating time (See Fig 434) The main arteries and veins are carefully isolated and gias The bone end having been cared for, the tourniquet is loosened and all bleeding points are clamped and ligated An approximating layer of interrupted sutures of silk or chromic catgut is used for the fascia care being taken to avoid inclusion of the muscle Ordinarily, fascial flaps are planned to correspond with skin flaps, but allowance must be made for their inelasticity Muscle in large amounts quilted over the

Fig 300 Before (*left*) and after (*right*) excision of scapula for osteochondrosarcoma Procedure successful no local recurrence (Courtesy, Amer Jour Surg, 35 473)

doubly ligated with heavy silk or chromic catgut The nerve trunks are isolated and dissected proximally to permit of high ligation, after which 1 per cent novocaine followed by 95 per cent alcohol is injected slowly with a fine gauge needle so as to swell the nerve trunk above the ligatures The part of the nerve below the ligature is then excised, thus avoiding the later development of terminal neuromata or causal bone is undesirable for it soon becomes edematous cicatrized, painful, and renders limb fitting difficult Skin closure is obtained by interrupted sutures of silkworm gut or silk placed about 4 cm apart with further coaptation by means of Michel metal clips or fine silk sutures

In amputation stumps especially of the upper arm and thigh it has always been considered that some provision must be made for the escape of the serosanguineous fluid which inevitably accumulates where a limb is completely bifided These drains, however, should be of small cabber, soft,

* A tourniquet is not applicable for interscapulothoracic disarticulation and therefore the subclavian vessels should be secured at the outset This is best accomplished by resection of several inches of the clavicle (see Fig 302)

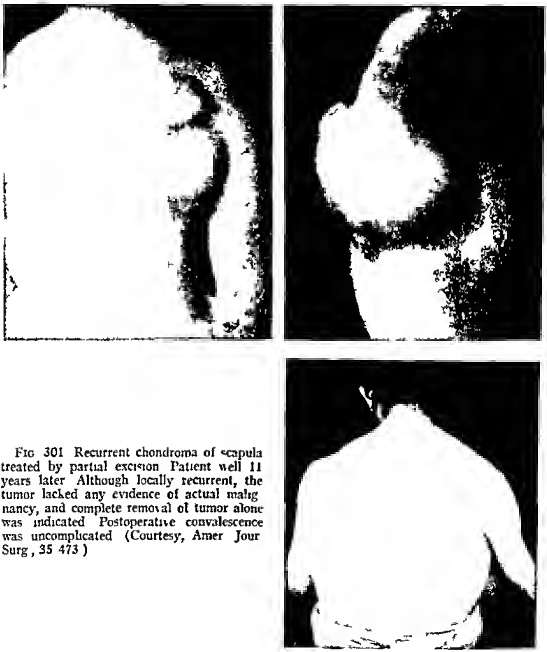


FIG 301 Recurrent chondroma of scapula treated by partial excision Patient well 11 years later Although locally recurrent, the tumor lacked any evidence of actual malignancy, and complete removal of tumor alone was indicated Postoperative convalescence was uncomplicated (Courtesy, Amer Jour Surg, 35 473)

and so placed as to avoid contact with major vessels furthermore they should be readily removable Soft rubber tubing of the size used for Carrel Dakin tubes is satisfactory for thigh amputation In the upper extremity and in leg amputations roll rubber dam is used During the past two years the writer has gradually become convinced that by using silk throughout for all buried ligatures and sutures a complete closure of the amputation stump can be safely performed This step has improved the course of these cases markedly The dressings are reduced in number and the period of hospitalization shortened Primary wound healing without drainage has resulted in every instance where silk alone has been used In only one case was there a late development of a sinus which healed after extrusion of a silk knot

Radiation Radiation therapy in osteogenic sarcoma has not produced encouraging results Recoveries have been exceedingly rare While in some cases that have received heavy radiation prior to amputation no viable tumor tissue was recognizable on histologic examination in the majority of cases it must be admitted no such profound change has taken place Clinical experience shows that after a maximal dosage of high voltage radiation has caused an apparent arrest of the activity of the tumor accompanied by relief of all symptoms and cessation of growth later there occurs a reactivation of the tumor with extension of the disease distant metastases and death

Coincident with the disappearance of pain and diminution in the size of the tumor following intensive radiation there is a nearly constant reduction in the serum phosphatase levels Moreover tissue phosphatase in heavily radiated tumors is reduced in comparison with cases amputated without preliminary radiation

Attempts are still being made to control the primary growth with radiation by the supervoltage machine (1 000 kilovolts) It is too early to assume that a complete control and ultimate cure can thus be attained

In the light of the foregoing remarks, we believe that the highly malignant forms, which make up the majority of all osteogenic sarcomas may profitably be treated by preliminary radiation If the case is operable, and permission for amputation can be obtained this procedure should follow the radiation cycle and should not be unduly deferred

In cases having an inoperable setting or where permission for amputation is refused

FIG 302 Sclerosing osteogenic sarcoma Interscapulothoracic disarticulation indicated

radiation should be administered for its possible relief of pain and prolongation of life

Radiation for pulmonary metastases, however is of questionable value Where only a small solitary metastatic node is present it has been our practice to crossfire it by using small portals accurately placed but in general neither prolongation of life nor added comfort is gained by the radiation of pulmonary metastases of osteogenic sarcoma

Roentgen therapy Technic It is not within the province of this chapter to discuss in detail the methods of administration the dosage, or other factors concerned

in high voltage therapy The surgeon must cooperate with a well trained radiologist and the latter's decision regarded as final Care should be exercised in planning the portals so as to include the widest zone possible on all sides of the area actually involved by the disease If this is not done, some outlying portions may go untreated Excessive radiation of the soft tissues at or adjacent to the level of proposed amputation should be avoided, otherwise imperfect wound healing will complicate the post operative course

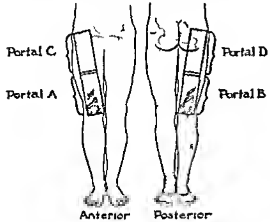


Fig 303 Diagram of method of treating osteogenic sarcoma of lower femur—four portals two anterior, two posterior Note entire length of femur is treated

A single example of the method employed at the Memorial Hospital for the preoperative radiation of an osteogenic sarcoma of the lower femur is cited as follows (see Fig 303)

Two rectangular portals anteriorly and two posteriorly are outlined to include the entire extent of the bone The daily dose varies depending upon the patient's tolerance to the radiation, usually 200 roentgens is given to each of two fields daily As illustrated in Fig 303, portals A and C, and D and B receive treatments on alternate days The lower portals, A and B, are usually given the maximum amount that can be tolerated by the skin This is from 2400 to 3000 roentgens The upper fields must not receive sufficient radiation to interfere with wound healing following the amputation of the limb at a later date The total dose to these portals is from 1400 to 1800 roentgens Of course, if no operation is planned because the patient's consent is withheld or because the disease has reached an inoperable stage, all portals are then given the maximum dose

The factors usually employed are 200 to 250 kilovolts, a current, 30 milliamperes 50 cm target skin distance, and 1 5 Mm of cu filter

Results in a Series of 219 Cases of Osteogenic Sarcoma (Histologic Confirmation of Diagnosis) Observed at Memorial Hospital from 1921 to 1938

Indeterminate Group	
Dead of unassociated causes and without recurrence	1
Lost to follow up without recurrence	13
Total	14
Determinate Group	
Failures	
Dead of sarcoma	166
Lost to follow up, with disease	0
Living, with disease	13
Total failures	179
Successful Results	
Free of disease five or more years	26
Five year survival rate	12%

Endothelioma of Bone (Ewing's Sarcoma)

This highly malignant primary bone sarcoma which, in most instances, involves the shaft of a long bone, is usually found in children and in young adults, and but seldom in individuals past the age of 25. It never involves the epiphysis primarily It has a fairly characteristic roentgenographic appearance, however, examples are frequently encountered of close resemblance to osteogenic sarcoma and certain benign bone conditions—notably, pyogenic osteomyelitis Tuberculosis of bone, luetic periostitis, and typhoid osteomyelitis are far less frequently confused Because of its close similarity to subacute or chronic inflammatory bone conditions, close attention must be paid to the patient's history, the physical findings, and all laboratory procedures in order to arrive at a correct diagnosis of endothelioma In the final analysis, the microscope is the most important factor, and yet there are instances where a microscopic examination may be misleading.

Several cases have been observed in which a biopsy has been performed after one or two rather mild exposures to roentgen rays In these, while the sections revealed no demonstrable tumor tissue and the pathologist reported only "osteitis" or "inflammation," the subsequent developments proved this optimistic diagnosis to be ill-founded, in each instance the endothelioma proved fatal. This error has led to the adoption of the rule that *in no case of suspected endothelioma should a single exposure of roentgen ray be given prior to biopsy or before the diagnosis has been definitely established by microscopic examination.*

Biopsy. Experience shows that by aspiration biopsy a correct diagnosis is possible in a high percentage of cases and is recommended in preference to operative biopsy—assuming, of course, that the former is performed at a hospital where the pathologist is equipped to make a diagnosis from this sort of material. The *technic of aspiration biopsy* has already been described [See p. 341.—Ed.]

For surgical biopsy, the most meticulous care in wound closure is essential, perhaps more so for this type of tumor than for any other. Here there is a tendency toward profuse bleeding, rapid growth through the wound, and fungation at the surface. [See comments on surgical biopsy in osteogenic sarcoma, p. 342 —Ed.]

Fig 304 Endothelial myeloma of femur suitable for preoperative radiation followed by hip joint disarticulation

Treatment. Since this is one of the most radiosensitive of all tumors, a well-planned course of radiation should be given in every instance after the diagnosis has been established. Instead of a prolonged course with small daily doses, we believe a shorter series using larger doses is preferable. One should

utilize all available portals and treat the entire length of the affected bone from one articular surface to the other For example, if the primary involvement is in the mid portion of the femur, the portals chosen may be as follows upper anterior, upper lateral, upper posterior and lower medial, lower anterior, lower lateral and lower posterior This gives seven portals and a dosage to each port of 500 r may be given every seven days until 2000 r have been delivered to each port assuming that but one port is treated per day Or a smaller dose, 300 r, may be used, and two ports treated each day until all have received eight exposures of 2400 r

Following this treatment, the question of an amputation must be considered Since the records of the Bone Sarcoma Registry contain only one five year survival of endothelioma treated by radiation alone, some authorities favor amputation after preliminary radiation Others believe that if no disease has been demonstrated beyond the scope of the primary radiation, the latter will be sufficient to control the local disease and that, therefore, an amputation is unnecessary It is very difficult to decide which of these hypotheses is correct because no matter how these cases are treated more than 90 per cent have a fatal termination

It is obvious that in a disease in which the treatment is so far from ideal, there will always be a wide divergence of opinion on therapy and the attitude of the profession will change from time to time At present either amputation or resection of the affected bone—the latter in exceptional cases—seems justifiable, especially when a bone of the lower extremity is involved Even though the prospect of a cure by any method is remote, there is less compulsion in urging an amputation for an endothelioma of the upper extremity One should invariably amputate proximal to the affected bone—never through it Since this disease shows an even greater tendency to extend along the shaft beyond the limits of apparent clinical or roentgenographic detection, unless this precaution is followed a recurrence in the stump is almost inevitable

Constitutional Therapy Mixed Toxins of Erysipelas and *Bacillus prodigiosus* (Coley) The use of toxins for this form of sarcoma has been advocated by William B Coley It has been part of the therapy, in conjunction with radiation and amputation, in a majority of the small number of registered cases (Bone Sarcoma Registry) that has passed the five year survival period * It is we believe worthy of continued use in this disease, in which less than 5 per cent of the patients live for five years or more We are quite unable to predict the value of the toxins in a given case, but we will continue to make it a part of the treatment until further studies disprove its value While we admit that most of the cases of our personal series in which toxins were used ultimately succumbed, still we have no five year survivals of endothelioma in which the toxins were not included as a part of the treatment (See table, p 351)

Plasma cell Myeloma

This condition sometimes termed *multiple myeloma*, has an almost hopeless prognosis It attacks those past middle life rarely appearing before the age of 45 (The skull, ribs, spine, and pelvis, as well as the major long bones are the sites of destructive areas of bone resorption) Its nature precludes any form of surgery other than biopsy Solitary lesions have been described and we have encountered them, however, in no recorded case has the condition remained solitary or confined to a single area, later manifestations include a multiplicity of lesions

Aspiration biopsy is peculiarly adapted to establishing the diagnosis in this disease Most of our cases have had successful aspirations [For technic, see p 341 —Ed]

* The toxins were used in six of the 11 five year survivals of endothelioma in the Bone Sarcoma Registry (1940)

Results in a Series of 71 Cases of Endothelioma (Histologic Confirmation of Diagnosis) Observed at Memorial Hospital from 1921 to 1938

	Cases
Indeterminate Group	0
Determinate Group	
Failures	
Dead of endothelioma	62
Lost to follow up, with disease	2
Living, with disease	2
Total failures	66
Successful Results	
Free of disease five or more years	0
Living, free of disease, under five years	5
Five year survival rate	0%

Treatment While roentgen therapy has produced marked palliation in some cases, in others the effect has been transitory or insignificant It should, however be used in an effort to alleviate pain, and should be pushed vigorously in cases where the lesion is solitary or where the disease involves only a few areas It is occasionally possible to obtain regression and sometimes extensive bone regeneration and a comfortable state of health for a period extending over several years

Pathologic fracture is a common occurrence, and may heal promptly following a moderate dose of roentgen ray Extremely heavy doses are to be avoided as they tend to prevent appreciable reparative bone reaction

While Coley's toxins have been given an extensive trial in a number of cases, the results have not been encouraging and we have abandoned the method in this type of tumor

The rarer examples of tumors in the myeloma series (myelocytoma, erythroblastoma, lymphocytoma) are so seldom encountered that little may be said of their treatment For the most part they are exceedingly fatal and seldom offer opportunities for successful application of either surgical or radiation therapy

Reticulum cell Sarcoma of Bone

This rare form of primary bone tumor has only recently been definitely established as a distinct clinical and pathologic entity Parker and Jackson (1939) have collected 17 cases, including those entered in the Bone Sarcoma Registry and those observed in several large Boston hospitals Personally, we have noted eight cases in which the diagnosis was confirmed by competent histologic examination

So closely may the clinical and roentgenographic features of this type simulate osteomyelitis, endothelioma, osteogenic sarcoma and even Hodgkin's invasion of bone, that the diagnosis is seldom established until a study of tissue sections has been made

The condition is osteolytic, and the new bone that may be seen in radiographs is reactive and not tumor bone It occurs near the metaphysis but may extend to the diaphyseal region It seems to expand the bone by pressure from within outward Overlying muscles may be invaded by direct extension

Treatment Obviously, in a disease as rare as this, the mode of therapy is less firmly established than in diseases offering a greater opportunity for evaluating the various methods in use However, since the

lesion is definitely radiosensitive it has seemed to us that Parker and Jackson s recommendation of amputation is somewhat open to question We have used radiation in all of our cases in no case was amputation performed

Until the results in a larger group of cases have been compiled particularly with respect to the five year survival rate by the several methods of treatment i e amputa t on alone rad ation alone and amputation followed by radiation of regional lymph nodes (as advocated by Parker and Jack son) it is obvious that no hard and fast rules for treatment can be given It seems preferable to rely chiefly on intensive roent gen therapy to the affected bone and to reserve surgical measures for cases in which complete and lasting regression has not been obtained

Liposarcoma of Bone

This is a rare variety of bone tumor Its identification is difficult if not impossible by clinical and roentgenographic examination and is usually made on histologic study only It is an osteolytic lesion but may provoke reactive bone formation adjacent to the area actually involved It is usually medullary in orig n It is easily confused with osteolytic forms of osteogenic sarcoma

Treatment This tumor is not so re sistant to radiation as are most forms of osteogenic sarcoma Therefore radiation therapy is worthy of an extensive trial Amputation has resulted in several five year survivals Less rad cal surgery is seldom feasible

Metastatic Carcinoma of Bone

The frequency with which skeletal meta stases occur in carcinoma of the various organs is unquestionably far greater than is generally recognized for many of these deposits in bone are silent cause no symp toms and are not discovered Those that cause pain swelling or a pathologic frac ture are the only ones that ordinarily are radiographed and thus brought to light Certain cancers are much more prone to skeletal metastases than are others for example those originating in the prostate breast kidney thyroid lung or stomach are far more frequently found to have secondary osseous deposits than are those in the female genital tract The important th ng is to recognize the bone metastases as such not confusing them with primary bone tumors myelomas or hyperparathyroidism As a matter of fact metastatic bone cancer exceeds in frequency all primary malignant bone tumors combined

Treatment The prognosis under any form of treatment is absolutely hopeless yet in many instances relief of pain and prolongation of life are accomplished by radiation Roentgen therapy should be planned so as to deliver effective doses to all the areas involved It is unnecessary to state that the entire skeleton should be examined rad ographically before com mencing therapy

Extensive multiple involvement is usu ally associated with anemia When to this is added the anemia produced by extensive treatments of wide areas by roentgen ray it becomes apparent that liver and iron therapy vitamin administration and occa sionally transfus ons are a necessary part of the treatment

Since rad ation is employed chiefly for relief of pain very heavy or prolonged ex posures are not advisable They may pre vent bone regeneration which, in radio-sensitive growths may take place to a remarkable degree Palliation at times is striking and may be prolonged for a year or two occasionally even longer Usually the response to the second or third cycle of radiation is less marked and there comes a time in every case when it is better judgment to suspend all active therapy

Surgical Measures While the ind ca tions for chordotomy are less often met in metastatic bone cancer than in primary malignant disease of bone there may be an

occasional case in which this procedure must be considered

Posterior root section or alcohol injection are two palliative measures that have not hitherto received the consideration they deserve The use of these procedures in a given case depends upon many factors some anatomic and others general They are less likely to be of value in cases in which the expected span of life is short than in those with a slowly growing tumor indicating a long period of intense suffering

[*In the last few years it seemed to be* demonstrated that in cancer of the prostate with bone metastases striking regression and even disappearance of the metastatic lesions followed complete castrectomy often with apparent regression in the primary tumor Prostatic cases with known bone metastases or with high phosphatase levels indicative of bone metastases should be offered the hope inherent in complete castrectomy Unfortunately however the permanency of this change is now regarded with doubt Radiation to the testicles is not a substitute for operation —Ed]

PATHOLOGIC FRACTURE

The treatment of this rather common complication of bone tumor depends upon the exact nature of the bone lesion i e whether primary or metastatic benign or malignant, single or multiple

Some benign lesions require conservative surgery or mild radiation and the fracture then heals satisfactorily

Where pathologic fracture complicates a primary malignant tumor of bone amputation is generally inevitable, although whether it should be performed immediately or after preliminary radiation depends upon all the factors of the individual case In general the outlook is bad and the amputation serves palliatively by ridding the patient of a painful encumbering and functionless member

By far the most common cause of pathologic fracture is that due to metastasis from some cancer located elsewhere The organs most often the primary seat of bone metastasizing tumors are breast, kidney, thyroid adrenal and prostate

An early diagnosis adequate support and radiation therapy may in many types of bone tumor delay or even prevent a pathologic fracture

Amputation is seldom justified for pathologic fracture due to metastatic carcinoma, particularly because of the completely hopeless outlook often there are other widespread areas of disease so that the expectancy of life is short In the exceptional case where radiographs of the remainder of the skeleton fail to reveal any involvement, radiation and suitable immobilization are indicated Particularly in breast carcinoma with pathologic fracture of the vertebral bodies, much can be done for the patient s comfort by proper support with plaster corsets, jackets, or spinal braces, coupled with radiation therapy We have seen a patient with paralysis of both lower extremities treated by such measures survive in comfort for several years Judgment is required in assaying the proper advantages of radiation therapy in these pathologic fractures, and a knowledge of the probable radiosensitivity of the tumor has proved helpful

B TREATMENT OF TUMORS OF JOINTS

BRADLEY L COLEY, M D, AND JOHN C PIERSON, M D

Tumors of joints, tendon sheaths, and bursae are uncommon, but they undoubtedly occur more frequently than reports in the medical literature would indicate Since their treatment is dependent upon a knowledge of the various forms of tumor that are encountered in these locations the following classification may be useful

Benign Chondromatosis
Ganglion
Xanthomatous giant-cell tumor
Cysts of semilunar cartilage
Lipoma
Fibroma
Hemangioma

Malignant Synovioma
Fibrosarcoma
Myxosarcoma
Liposarcoma

BENIGN TUMORS

CHONDROMATOSIS

This condition is characterized by the formation of multiple, discrete, pearly cartilaginous bodies which may be free in the joint or attached to the synovial membrane It is found in adults between the ages of 20 and 50, and is seen more often in men than in women The knee, elbow, ankle, hip, and shoulder are the joints involved in order of frequency Symptoms are mild pain, swelling, and stiffness of a joint A characteristic feature is the variable site of pain which may occur at widely differing parts of the joint in successive attacks Differentiation from monarticular forms of arthritis may be done with the x ray film which shows numerous spotted calcified nodules

Treatment The treatment, depending on the severity of symptoms, may be conservative, or the loose bodies and synovial membrane containing them may be excised

GANGLION

This is a common condition usually found on the dorsum of the wrist, but it is also seen occasionally on the dorsal surface of the foot or ankle It is a soft, well-circumscribed cystic tumor which starts by cellular thickening in the capsular ligament Later multiple cysts are formed by collagenous degeneration the walls of which eventually break down to form a monolocular cyst containing fluid similar to concentrated synovial secretion It is frequently preceded by a strain or trauma In some instances a ganglion may communicate with the joint cavity, however, this condition is not generally considered to be the herniation of a synovial membrane

Treatment. Excision under the aseptic conditions of the operating room is the most satisfactory form of treatment This minimizes the likelihood of infection should the joint be entered A transverse incision as recommended by Bunnell leaves the best scar and allows adequate exposure The wound is closed without drainage, and the wrist may be immobilized on a cock up splint for a few days, although this is not essential Recently the injection of sclerosing substances, such as phenol in glycerine, tincture of iodine or sodium morrhuate, has been employed with varying degrees of success It should be borne in mind, however, that serious joint disabilities may be caused by chemical irritation, where the substance comes in contact with the joint [See also

clinical features are pain, more or less constant, and local swelling The tumor is usually palpable just above the head of the fibula It is fixed, nontender, and often fluctuating

Treatment This consists of excision of the cartilage and its cyst The operation is best done under a field rendered bloodless by a tourniquet and with the patient under general anesthesia The Fisher, Jones, or Cave incision may be employed These are curved incisions the last being horizontal over the tumor and curving upward at almost a right angle at its posterior extremity According to Campbell, the cyst is usually situated anteriorly so that removal of the anterior two-thirds of the cartilage will suffice If the cyst extends posteriorly the entire cartilage should be removed Care should be taken that the external lateral ligament is not injured After suturing the synovial membrane and the joint capsule the incision is closed with interrupted sutures or clips A firm bandage is then applied and the limb is immobilized by a posterior molded plaster splint holding the knee in slight flexion the position of maximum comfort Active motion may be allowed on the fifth postoperative day, and walking on the ninth day [See Chapter 38 for further discussion of technic in knee joint procedures —Ed]

Lipoma

Lipoma of joints is rare Most reported cases occur in the knee or ankle, and are often associated with hydrarthrosis Some of these tumors may be visualized by radiographic studies The treatment, however, consists in exploration of the joint and removal of the lipoma If diffuse lipomatosis is found, complete synovectomy may be required to relieve the symptoms

Fibroma

This tumor rarely affects the joints or tendons It is nodular, hard, of extremely slow growth, and is usually painless and only slightly tender The treatment is surgical Excision is sufficient but in certain locations this may require partial capsulectomy As in operations upon the fingers in general, one should endeavor to expose the tumor through lateral incisions to avoid a scar that is tender and may limit full function

Hemangioma

Razemon and Bizard in 1931 collected 74 cases of primary tumors of the joint of which 17 were angioma Geschickter and Copeland reported two cases from the Johns Hopkins Hospital laboratory, and Haas described a case of hemangioma of the knee which had invaded the lower portion of the articular surface of the femur producing bone destruction

In a personal communication, Krida* states that he has operated upon three cases of extensive hemangioma of the knee joint apparently of synovial origin The diagnosis was made at operation in the first two cases and preoperative clinical diagnosis was made in the third case on the basis of a boggy thickened synovial membrane, slightly increased local heat, and, particularly, on the presence of a small superficial mass of dilated veins overlying the patella This was a finding in the two earlier cases, the significance of which escaped observation He describes these cases briefly as follows

Case I, male aged 48 years, who presented, in the x ray, advanced osteo-arthritic changes in the knee joint, some abnormality of the knee joint having been present for many years

One year after synovial excision, this patient came under the care of another surgeon who performed an amputation in the belief that there had been a recurrence of the tumor Examination of the specimen, however, revealed no evidence of a recurrence

Case II, female, aged 34 years, had an arthrotomy presumably for a torn semilunar cartilage six years prior to operation by Dr

* Arthur Krida M D New York personal communication dated November 14, 1941

Krida The latter excised a large synovial hemangioma involving the whole of the interior of the joint Patient pronounced clinically cured eight years later

Case III, male, aged 21 years, whose symptoms were of a minor nature but who presented a boggy enlarged knee joint with significant varicosities A complete excision of the hemangioma was done, and the patient was pronounced clinically cured one year later

These tumors occur most frequently in young adults They usually develop in the knee joint Symptoms are intermittent pain and swelling often associated with activity *Some observers have found the tumor to* have a characteristic boggy feeling, occasionally pulsation can be felt

Treatment Arthrotomy and excision may be done where the tumor is well localized Krida employs the "general utility incision," *i e* the median parapatellar incision [See knee joint operative technic, Chapter 38 — Ed]

In the case of extensive involvement irradiation therapy is preferred This failing, recourse to complete synovectomy or joint resection may be necessary Careful hemostasis is especially important as severe hemorrhage may otherwise result, although no case of fatality has been reported If the tumor is accessible, sclerosing solutions such as sodium morrhuate may be of value A 5 per cent solution is used and the treatment carried out in stages until sclerosis of the injected portions has been accomplished High voltage roentgen therapy has been successfully employed It is advisable to conclude an incomplete operation upon an extensive tumor by postoperative irradiation

MALIGNANT TUMORS

Synovioma

This lesion arises from synovial membrane and may, therefore, be found wherever synovial tissue exists It may occur as an intra- or para articular tumor It is highly malignant, although some authors believe that less malignant forms are sometimes encountered It is of rare occurrence, however, case reports have appeared with increasing frequency since its identification by Smith in 1927 A small painless lump situated near a joint may be the only sign The most frequent site is the knee, other joints being the fingers, ankle, and metatarsus None has been reported in the hip, elbow, or shoulder (we have however, encountered a case involving the shoulder) [A case involving the elbow has been treated by Dr William Darrach on the Fracture Service of the Presbyterian Hospital It was *treated by disarticulation at the shoulder*, and was free from any evidence of metastases for nine years, but is now showing evidence of pulmonary metastases —Ed] Adenopathy does not occur and the signs and symptoms are of little aid in the diagnosis which is determined definitely by biopsy

Treatment Any operable tumor of the joint which by its location, suggests the possibility of a synovioma should be widely excised Indeed, the possibility of a synovioma should prompt one to excise widely any suspicious nodule near a joint If histologic study confirms the diagnosis then postoperative radiation by the fractional dose method may be given, although its value is open to question If the disease recurs, an amputation is imperative, providing the lungs are free of metastases *Moreover, if a complete excision is impossible*, immediate amputation should be recommended If inoperable, or if amputation is refused, roentgen ray or radium therapy should be employed Coley's toxins may be of value as a prophylactic measure against recurrence or metastasis In general it is believed that early treatment has been far too conservative, thereby rendering later measures ineffectual The point of election for amputation in cases occurring in the knee is the midthigh, for those in the ankle, about six inches below the knee, and for those in the hand, at the midforearm

When these malignant tumors invade the

hip joint, pelvis, spine, shoulder girdle, or other inaccessible portions of the body, radical operative interference is generally inadvisable Such operations are seldom successful and they carry a high mortality A possible exception may be made in the case of the shoulder, where, if the disease is localized to the shoulder joint, it may be removed by interscapulothoracic amputation

As to the form of radiation to be employed, implantation of radon gold seeds or removable radon needles is seldom applicable to this group of malignant tumors External radiation by roentgen rays or the radium pack is preferable, although only palliative in effect

Preoperative radiation cannot be considered a sound procedure, for not only does it delay the diagnosis but also it increases the difficulty of operation, predispo es to infection, increases morbidity, and makes an evaluation of surgical and radiation therapy most difficult

Postoperative radiation should be given where complete excision has been impossible The proper dosage is a highly technical problem which requires special knowledge

Fibrosarcoma, Myxosarcoma, Liposarcoma

These tumors may arise from the joint capsule or invade it by direct extension They are rare, but as in the case of synovioma may be relatively localized in the early stages Signs and symptoms are by no means characteristic Pain may be severe, especially so in recurrent lesions Effusion may be seen where the tumor has become very large, thus leading to pressure and irritation

Treatment In general the treatment should follow the same principles as those laid down for synovioma Amputation promises the best outlook where the tumor is situated below the knee or elbow joint

Wide local excision of neoplastic disease involving joints is indicated only for benign tumors, the malignant types being best treated by amputation Often the disability incident to an amputation and the wearing of an artificial limb is less than that which follows a resection Joint resection is, in general, inadvisable

Lipoma, fibroma, and joint cyst are usually localized so that wide exposure of the joint is unnecessary, but xanthoma, hemangioma, and, in rare instances, diffuse chondromatosis may involve the entire synovial membrane In such cases complete synovectomy must be done All diseased tissue must be removed Should the crucial or lateral ligaments be divided in the knee joint, the fibrosis resulting from so extensive a procedure lends support to the joint

Impairment of function following synovectomy may range from 50 to 15 or 10 per cent, the wide difference being explained by the age of the patient as well as by the duration and nature of the pathology

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13

Tumors of Muscle, Fasciae, and Tendons

CLAY RAY MURRAY, M D

MUSCLE TUMORS

BENIGN TUMORS

Primary muscle tumors are rare By far the majority of them are benign in nature, and require nothing more than local excision with repair of the defect created by operation (See Chapter 42 for technic of muscle suture) A characteristic useful in diagnosis in benign muscle tumors is the fact that they are freely movable when the muscle involved is relaxed, but are fixed when the muscle is contracted Absence of clearly defined limits and progressive and rapid increase in size should lead to suspicion of malignancy, and prompt biopsy for diagnosis Suspected hemangiomata, however, should be biopsied with caution (see below)

Among the benign tumors which are well encapsulated and which can be treated by the technic described above are (1) the fibromata, which are firm, and may feel almost cartilaginous, (2) the lipomata, which are soft and even semifluctuant, and (3) the rhabdomyomata, which appear distinctly circumscribed and in which the muscle fibers on microscopic section appear for the most part normal and adult, with striations approaching the normal in appearance Occasionally the striations are indistinct and difficult to see, and only the staining reaction and the fact that the nuclei are present in parallel arrangement along the edges of the broad fibers composing the tumor identifies its real character

All supposed benign tumors should be biopsied at the time of, or preliminary to, their removal A supposed benign fibroma may be a fibrosarcoma or an early spindle cell sarcoma, and a supposed benign rhabdomyoma may be an early example of the malignant and serious form

One form of fibroma situated in muscle is of special note This occurs in the anterior abdominal wall, and most frequently in the rectus abdominis The vast majority of the cases—90 per cent or more—occur in women, but rather infrequently in nullipara These are commonly known as desmoid tumors, and have been called recurrent fibroids by Paget because of a tendency to recurrence after removal They are nevertheless usually considered benign and never metastasize When they are encountered, however, they should be rather widely removed

Hemangioma of muscle occasionally exists as a localized mass resembling a lipoma in consistency Sometimes, as a result of an arteriovenous aneurysm, a bruit can be felt Such tumors usually are of the cavernous type, but they may merely represent a collection of dilated veins which is not properly a tumor If they are opened into in the course of removal, the bleeding is very brisk and difficult to control It is therefore wise to use a tourniquet in their removal, and if the condition is suspected before operation a venogram is exceedingly helpful in con

firming the diagnosis and in giving a definite idea of the extent and character of the tumor The commonest sites are in the biceps and triceps muscles in the upper arm, in the muscles of the forearm and in the muscles of the lower leg, particularly the calf muscles, and the sternomastoid The tumor is not particularly amenable to x ray or radium treatment, and excision or cautery (or both) is the indicated form of treat ment Sclerosing injections have been used but they have not been proved of value to date

The taking of a venogram when heman gioma is suspected is the part of wisdom for another reason What appears to be a localized tumor to palpation and soft part x ray may in fact be an extensively infil trating mass When the diffuse or infiltrating form is present whole muscle bellies—or most of the muscles of the part together with the subcutaneous tissues—and the fascia may be involved Such cases present a major problem in surgery, and a venogram may prevent operation on a diffuse and in filtrating mass of venous channels which is far too extensive for removal, and which may require amputation Ill advised at tempts at removal of these diffuse lesions of large extent frequently end in disaster The distribution of these tumors is that de scribed above for the localized form

Malignant Tumors

The primary malignant tumors of muscle are (1) the fibrosarcoma (spindle cell), and (2) the rhabdomyoma of the embryonal type The two are often confused, since the mixed tumor may contain muscle fibers of embryonal type To be classed as rhabdo myoma of the embryonal type the tumor must be composed practically of only em bryonal muscle fibers in the form of long or short spindles showing definite transverse striations

Fibrosarcoma in muscle arises from the connective tissue elements therein It varies greatly in its speed of growth Early in their course, when small, they are usually well-encapsulated and can be removed without difficulty Later they often tend to grow more rapidly, to infiltrate and then to metastasize Even when small they tend to recur locally after excision They are quite variable in their response to x ray and radium, and these agents can be safely used only in conjunction with surgery

Wide local excision under tourniquet fol lowed by x ray or radium is indicated for the early well circumscribed and easily re movable tumors If the infiltration is con fined to a single muscle, or to a removable group of muscles complete excision under tourniquet of the affected muscle or muscle group may be possible wide of any evidence of tumor If so the procedure should be fol lowed by the use of x ray or radium Biopsy at the time of operation may be of great help in deciding on the wisdom of excision as opposed to amputation in these cases in accordance with the apparent malignancy indicated by the sections Where the tumor is rapidly growing and definitely infiltrat ing or when it is so extensive as to preclude wide excision of all affected tissue, amputa tion well above the upper limits is indicated, followed by x ray to the regional nodes Prophylactic x ray to the lungs is not today regarded in general as of value or indicated

Needless to state, when fibrosarcoma is suspected, preliminary x ray of the lungs for metastases is essential before *any* oper-ative procedure is contemplated, since the presence of lung metastases is an absolute contraindication to operation, and an indi cation for palliative x ray therapy

Overconservatism in resorting to local ex cision, particularly after one or more local recurrences, is a fault in the treatment of these cases The behavior of the tumors is so variable that it is often difficult or impos sible to tell what is going to happen

The embryonal rhabdomyomata are dis-tinctly malignant in nature The author has seen three proved cases evidenced by dif fuse enlargement of the muscles of one side

of the back. One of these cases was picked up in a routine school examination. In each instance the tumor was extensive and infiltrating, and all three died with direct extensions involving the spine and ribs and with generalized metastases to the lungs, despite extensive and apparently complete removal in two of them. They are not radiosensitive, and radiation or radium in themselves or postoperative are not of help. The prognosis is distinctly bad. Radical excision and postoperative x ray, however, are all we have to offer.

FASCIAL TUMORS

There are only three types of tumor which are commonly primary in fasciae. They are (1) the fibromata and (2) the xanthic tumors which are benign, and (3) the fibrosarcomata (spindle cell) which are malignant.

Fibromata are rare. When they do occur they usually occur in the fascial sheaths of muscles. Assurance must be had by biopsy that they are not fibrosarcomata in an early stage. The treatment is local excision, which, however, should be wide because of the strong probability that they are early fibrosarcomata.

The xanthic tumors or xanthomata occasionally occur in fascia as small tumors, one to two inches in length. They are pinkish yellow or grayish yellow in color, and require nothing more than local excision. There is considerable question as to whether or not they are tumors. They may represent merely granulation tissue formation and lipoid degeneration with phagocytosis following injury and hemorrhagic infiltration. They are characterized by the presence of both "foam" cells containing the lipoid material and foreign body giant cells. They are well encapsulated, and are certainly not malignant.

The fibrosarcomata (spindle cell) of fascia are subject to all the remarks made in discussing the same lesion in muscle. Fibrosarcoma may invade the underlying muscle secondarily or the overlying subcutaneous tissues. The same general rules for treatment apply here as were cited for the same tumor in muscle. It occurs most frequently possibly in the fascia covering the scapular muscles.

TUMORS OF TENDONS

Tumors of tendon sheaths may be benign or malignant. Both are uncommon.

Benign Tumors

These include lipomata, xanthic tumors, the so called giant-cell tumor, and, much more rarely, fibroma or chondroma.

Lipoma. This occurs in the tendon sheaths in one of two forms. It may exist as (1) a solitary tumor, or (2) as a growth similar to the lipoma arborescens, which is found in the knee joint and in other joints. The commonest sites for fatty tumors of the tendon sheath are in the palm of the hand and in the region of the ankle.

Symptomatology is that of low grade tenosynovitis in the region affected with or without some noticeable enlargement. Since the tumors are slow growing and do not commonly produce much in the way of visible swelling, they are often treated for considerable periods of time as a chronic tenosynovitis without much success. Operative exploration is usually necessary to establish a positive diagnosis. Many of them give little or nothing in the way of symptoms. Where sufficient symptomatology is produced to constitute a disability, excision of the tumor mass plus any adherent tendon sheath is indicated. In the lipoma arborescens type considerable tendon sheath will occasionally have to be sacrificed.

Xanthic Tumors. The xanthic tumors nearly always involve the tendon sheaths of hand and fingers. They present the same picture as that described under xanthic tumors involving fasciae. [See above.] A history of injury is common, but one must remember that a history of injury to the hands is not unusual. They are again in-

cluded here with due regard for the fact that in accordance with the opinion of many they may not be true tumors, but may represent an inflammatory reaction to physical or other forms of trauma with the production of a granulation tissue like mass containing giant cells and characteristic so called foam cells containing lipoid particles They also contain changed blood pigment which is responsible for their color They are slow growing and produce little in the way of discomfort or disability unless they are constantly traumatized The treatment is simple excision with the involved portion of the tendon sheath

Occasionally a tumor with all the morphologic characteristics of xanthoma is seen in the tendon sheaths in the region of the ankle joint The author has seen one such case in which the process was an invasive one originating in the region of the peroneal tendon sheath and involving ultimately the ankle joint, the astragalus and the lower ends of tibia and fibula The tumor was not clearly defined except in the immediate vicinity of the tendon sheath but in the pathway of its invasion it was a yellow, relatively avascular tissue with all the microscopic features of xanthoma and without any appearance of malignancy Several attempts at excision were followed by a recurrence, and ultimately the case was cured by prolonged and extremely intensive deep x ray therapy

One other such case in the hands of another surgeon has come to the author s notice In this case, too, there was no microscopic evidence of malignancy, although the ankle joint, the os calcis, and the astragalus were all invaded This case was treated by amputation after repeated failures of local excision and relatively mild and short lived x ray therapy Whether these two cases represented actual tumor or inflammatory processes it was never possible to decide All cultures from the author s case were negative, and there were no microscopic signs of any of the ordinary inflammations

The so called giant cell tumor or myeloid tumor of tendon sheaths is the commonest benign tumor and is found almost exclusively in the flexor tendons in the palm, and nearly always in the region of the distal or proximal palmar crease It grows very slowly and produces very little in the way of symptomatology apart from mild symptoms of tenosynovitis in the affected sheath Ultimately a localized swelling becomes palpable This tumor is characterized by the presence of giant cells and presents quite the picture seen in giant cell tumors of other connective tissues—bone, for example

The histologic picture is not far different from that of xanthic tumors minus their foam cells and their hematin pigment The treatment is operative excision but the excision in these tumors must be rather wide of the actual tumor This is necessary because although they are classed as benign tumors, there is a great tendency for local recurrences In this respect they resemble the fibromata of muscle and fasciae, particularly those which occur in the sheath of the rectus muscle in the abdominal wall and in the muscles of the shoulder girdle X ray and radium are not effective in these tumors

Fibroma and Chondroma These occur, but they are exceedingly rare and the diagnosis cannot possibly be made by clinical means The necessity for surgical exploration usually reveals the tumor, the nature of which is recognized on gross appearance or by microscopic section They require only conservative excision as they show no tendency to recur

Malignant Tumors

The only primary malignant tumor which attacks tendon sheaths is sarcoma, which has been observed in the forearm and hand and in the ankle and foot Sarcoma of tendon sheaths in general is a rapidly growing and freely disseminated type of growth, although it frequently presents a considerable degree of differentiation Practically all the benign tumors are very slow growing so

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DISEASES OF BONES AND JOINTS

that any rapidly growing tumor of tendon sheath warrants very prompt surgical attention It is said that if diagnosis is made early enough wide local excision is feasible Certainly if it is attempted the tumor must be reasonably well circumscribed and small and the excision must be quite radical The tumor is relatively rare In the vast majority of cases attempts at local excision by the time a diagnosis is made in all probability represent an applied waste of time, and amputation at a safe level should be considered early enough to make it of value instead of after repeated failures with more conservative measures

Primary tumors of the tendons themselves are so extremely rare as to constitute a surgical curiosity There is not enough information really available on the basis of the few cases which have been described to discuss the treatment in these cases It is to be assumed, of course, that if this rarity should be encountered, it would probably be necessary to excise the affected portion of the tendon and to do a free tendon transplant (See Chapter 42)

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SECTION FIVE

DISEASES OF BONES AND JOINTS

14

Tuberculosis of Bones and Joints

FRANK D DICKSON, M D

Part 1

GENERAL CONSIDERATIONS

Tuberculosis of the bones and joints is always secondary to active and often long established tuberculous disease elsewhere in the body, and in children nearly always to disease of the lymphatic glands When ever and so long as an *individual is suffering* from active lymphatic tuberculous disease, the presence of tubercle bacilli in the blood stream in the form of a bacillemia is of frequent occurrence The commencement of a tuberculous focus *in or near a joint* is due to tubercle bacilli in the blood stream settling in an area devitalized by injury, or settling in such large numbers that they can survive without any such preliminary de vitalization Etiologically, then, tuberculosis of a joint must be considered as a local *manifestation of a constitutional disease,* and this conception of joint tuberculosis has an important bearing on treatment, as will be seen later It should be stated, however, that a joint, in a relatively small percentage of cases, may become involved by direct extension of tuberculosis from neighboring *tissues, such as bursae, tendon sheaths, and* other joints While not often seen, this should be kept in mind

Heredity probably plays an indirect role by handing down to the offspring a lessened resistance to the disease General causes, such as undernourishment, unsanitary living *conditions, and infectious diseases, are im*portant considerations in outlining treat ment

PATHOLOGY

It is not expected in a work of this type that the pathology of bone and joint tuber culosis be discussed It is necessary, how ever, to call attention to the tissues which *are or may be attacked, for such informa* tion is essential to intelligent treatment

Tuberculosis infecting a joint may in volve (1) synovia, or (2) the bone on one or both sides of the epiphyseal cartilage As yet there exists no accurate estimate of the relative frequency with which the pri mary involvement is synovial or is in the bone (epiphysis or diaphysis) It is prob able however, that primary involvement of the synovia is more common than is gen erally supposed, and that if all cases were diagnosed early *the percentage of primary* involvement in comparison with primary bone involvement would be much higher than present statistics indicate The involve ment of the shaft of the long bones by tuberculosis is relatively rare.

GENERAL CONSIDERATIONS OF TREATMENT

Since tuberculosis of the bones and joints must be looked upon as a constitutional dis ease, manifesting itself locally in one or more joints, it is evident that its adequate management must include (1) general treat *ment or (2) local treatment*

General Treatment

General treatment is of paramount importance, since the cure of a tuberculous joint infection necessarily requires sufficiently building up the general resistance to take care of the original source of the disease as well as of the local infection. All the tubercle bacilli in the body must be killed or encapsulated if recurrent tuberculous bacillemia is to be prevented. Such a bacillemia can still occur after a cure of a local focus in a joint unless the original focus elsewhere has been rendered inert and harmless. It is imperative then that the necessity of careful general treatment be appreciated and that it be recognized that such general treatment is essential, not only during the acute activity of the local joint infection but long after the local condition has been eliminated. The parent source of the local disease is often deep seated, silent, and too readily forgotten with the disappearance of the local symptoms. [This is particularly true in cases treated by operative fusion for the local disease. The insistence by the author on the necessity for prolonged general treatment before, during and for some time after a successful joint fusion is well worth noting.—Ed.]

General measures should employ all the recognized means of improving the general health and building up the individual's resistance. The measures most generally used are: Rest, proper diet, fresh air, heliotherapy, and artificial sun treatments.

Rest. Complete bed rest as long as there is any elevation of temperature is just as important in joint tuberculosis as it is in pulmonary tuberculosis, and should be enforced just as rigidly. Such bed rest should be in hygienic surroundings with well ordered daily routine.

Diet. Along with bed rest, a well rounded, high vitamin, remineralizing diet should be insisted upon. While considering diet, the claims that the feeding of spleen or splenic extract has a beneficial effect on tuberculous joint disease may be considered. The evidence up to the present time, while not conclusive, indicates that little or no benefit can be expected from adding spleen or splenic extract to the dietary list.

Fresh Air. It has been found that respiratory infections are held at a minimum and general health is at its maximum when a patient suffering from tuberculosis is housed in a ward or room open to the air. This does not mean, however, that ruthless exposure to extremes of heat or cold is desirable. A room temperature maintained at about 68° F. with a relative humidity of 40 to 50 per cent, the air being constantly changed by not too rapid or violent air currents, provides the best possible living conditions for the tuberculous patient.

Heliotherapy. Sunshine, which produces sun tanned bodies and a happy mental outlook, increases muscle tone, and possibly stimulates more rapid calcification in tuberculous abscesses and in the bone lesion itself, is a vital aid in the treatment of joint tuberculosis. It cannot, however, be said to be a specific. Rollier of Switzerland and La Grasso of Perrysburg, N. Y., feel that the sun's spectrum has a specific effect on surgical tuberculosis. The evidence available up to the present time does not fully support this theory. The usefulness of heliotherapy in the treatment of tuberculosis, however, is unquestioned. While sunlight is most effective in the mountains, it is satisfactorily effective at any altitude from the sea level up. When using heliotherapy, the objective sought is a complete sun tan without burn or blistering. To reach this objective and avoid burning, the body must be given gradually increasing doses of exposure to the sun's rays. This may be accomplished in various ways, but the following is simple and effective.

The entire body is exposed five minutes, front and back, on the first day. Each day the time is increased five minutes, front and back, if there is no excessive reddening of the skin. If the skin shows signs of erythema,

the next day s exposure is omitted The time of exposure is increased until the patient receives one hour of sun, front and back, daily This amount should be the maximum during the summer months, but may be in creased in the cooler months when the sun's rays are less powerful If the patient is protected from the wind, sunbaths may be given the entire year round, even in north ern regions, except in the extreme cold Heliotherapy does not, so far as can be determined, tend to bring about changes in hemoglobin, red blood count, or white blood count, nor does it alter metabolism Helio therapy does tan and benefit the skin, im prove the muscle tone, increase weight, and bring about a feeling of well being in those suffering from tuberculous joint disease The effect of overdosage is quite the opposite, and overexposure (resulting in severe ery thema of the skin, nervousness irritability and decline in general health) should be rigorously guarded against [In those indi viduals who are particularly susceptible to exposure to direct sunlight, exposure to the reflected rays of the sun, with protection against direct rays, will produce slower but excellent results Direct exposures should be made only in midmorning and midafter noon —Ed]

Artificial Sun Treatment Various lights have been devised as substitutes for the sun's rays Mercury quartz lamps give an abundance of shorter waves or ultraviolet light Carbon arc lamps give a more con tinuous spectrum resembling the sun Infra red lamps give longer waves and more heat Sunshine in the higher altitudes gives a maximum intensity of ultraviolet, while at sea level and in smoky cities practically all of the ultraviolet rays are filtered out yet comparable results have been obtained under both conditions It would seem, then, that it is impossible to make a positive statement as to which rays are most bene ficial for patients suffering from tuberculosis is inescapable that rays which approximate of the bones and joints, and the conclusion most closely the solar spectrum are to be preferred

Phelps, after careful investigation, came to the conclusion that the wavelength span lying between 320 and 380 millimicrons is best This span is found in sunlight and in carbon arc lamps, yet favorable clinical re sults are reported by those using mercury quartz lamps It may be stated that exact clinical indications for different sources of artificial sunlight have not yet been defined, and that artificial sun treatment, while it may be used as a substitute for sunlight, cannot be considered to be a complete sub stitute When using artificial sunlight, the character of the rays and the intensity of delivery of the lamp should be exactly de termined and frequent checks of these conditions made to guard against incorrect dosage and faulty physiologic effects The quality of the light in the carbon arc de pends upon the carbon used and on the current The effectiveness of the mercury quartz lamp varies with the age of the lamp and other factors It is also well to use arti ficial sunlight with care until the tolerance of the patient to it is established [In all heliotherapy the physiologic effect on the patient and his sense of well being are the criteria rather than the degree of tanning obtained It is often overdone —Ed]

Local Treatment

The measures employed locally in the treatment of tuberculous joint disease may be of two types (1) Nonoperative or (2) operative Unfortunately, there has been in the past and is at the present time some con troversy as to the proper place of each This controversy has served to obscure the real issues, which are to bring about healing of the involved joint, to control the parent focus and to restore the individual to nor mal activity The method pursued is of secondary importance—the cure of the dis ease is the primary objective, and intelligent evaluation of the condition to be met rather than blind adherence to any special method

should form the basis of treatment in each individual case

Experience has shown that, in its early stage, tuberculous joint disease may sometimes be arrested and the function of the joint still be preserved, in which case the subsequent repair may be sufficiently complete to restore the joint to a useful status To secure such a result, however, it is necessary that the arrest of the disease occur while there is still sufficient integrity of the joint to enable it to withstand active use once it has recovered When, however, the disease has progressed to a point where destruction of joint structures impairs the integrity of the joint recovery with a useful joint is impossible Unfortunately, most tuberculous joints come under observation at a time when the destructive process is far advanced and all hope of a useful joint must be abandoned Healing by fibrous ankylosis and with a few degrees of motion in such a joint is a liability in that the joint does not stand up under the strain of active use and is the seat of frequent periods of disability Furthermore, such a joint is a constant menace in that at any time there may occur a lighting up of the arrested tuberculous process There is but one result which can be looked upon as safe in a tuberculous joint which has passed into the destructive stage, and that is bony ankylosis

There need, then, be no controversy between the advocates of nonoperative treatment and those who speak for operative measures In early synovial joint tuberculosis without evident destruction conservative treatment should be given, and surgery has no place in the picture When this stage has terminated and actual destruction of the joint structures has occurred conservative measures may be continued, but only if they are leading to bony ankylosis At this stage, however, conservative measures may be advantageously abandoned and replaced by operative procedures, which will insure bony ankylosis in the majority of cases, and will materially shorten the period of convalescence The responsibility involved in continuing conservative treatment in the face of joint destruction is great, and the preponderance of evidence is in favor of turning to fusion by operation as the most reliable method of curing the local disease, of giving the individual a useful extremity, and of shortening the duration of rigid treatment regime

Nonoperative Local Treatment This consists in the use of traction or fixation to immobilize the joint, and relief from weight bearing to prevent trauma to the diseased structures

Traction Traction should be used in the acute stage which is characterized by acute pain in the involved joint, muscle spasm and increasing deformity There is no treatment to which these symptoms respond so quickly as to that of definite and accurately adjusted traction When the acute symptoms have abated, traction should be discontinued and replaced by fixation Traction distracts the joint surfaces and prevents the contact of bone with bone, such contact is necessary for bony ankylosis Long continued traction therefore, except in the occasional case, is contraindicated

Fixation When the acute symptoms in the joint have subsided, rigid fixation of the involved joint adequately protects it and favors the arrest of the local disease Fixation of a joint is best accomplished by the use of a plaster encasement or recumbency Immobilization by a brace is much less efficient and should be reserved for convalescent cases

Protection In weight bearing joints, the extremity should be relieved from weight bearing during the fixation period in order that the diseased tissues may be protected from trauma and increased destruction Such relief from weight bearing is best accomplished by the use of crutches plus elevation of the sole of the shoe on the unimpaired side so that the involved extremity hangs free and bears no weight

As the treatment of tuberculosis of the various joints is described, the conservative treatment of each will be discussed in detail

Operative Local Treatment The operative treatment in tuberculous joint disease has but one purpose, which is to accomplish a bony fusion of the bones forming the joint, since this creates the most favorable situation for healing of the local process and the recovery of the patient If successful this procedure has another advantage—it accomplishes in a few months that which Nature requires years to bring about and does it more effectively From the economic viewpoint operative treatment has a great advantage over conservative treatment for it cuts down the period of hospitalization and incapacity from years to months and effects a very material saving for the individual and the community

The chief points of controversy between those advocating nonoperative management of tuberculous joint disease and those favoring operative treatment are (1) the age of the affected individual and (2) the region involved There are very few experienced in the treatment of tuberculous joint disease, other than the enthusiasts for heliotherapy, who deny that in the adult operative fusion is the method of choice The chief difference of opinion centers in the application of operative treatment to children Certainly no attempt to fuse a joint in a child should be made until the age of six to eight years has been reached except in the hip and spine After that age the operation of surgical fusion can be successfully performed if it is done carefully and with due regard for the preservation of the epiphyses There are many however, who refuse to consider joint fusion before the age of 12 to 14 years or later This group may be classed as ultraconservative

As to the question of the region involved it may be said that a successful ankylosis by conservative treatment may be expected more often in tuberculosis of the spine and of the wrist than in other joints, and there are many who believe that these regions should be treated by conservative measures alone, and with some justification However, the consensus is that, even in the spine, fusion offers a better result and a more rapid recovery than does conservative treatment In the light of our present knowledge the position is justifiable which holds that all adults and those children over the age of eight years in whom conservative measures have not resulted in either a freely movable joint or in bony ankylosis should have the diseased joint fused by operation

Fusion operations will be described in detail in the discussion of the treatment of individual joints

Amputation Amputation must be considered a part of the operative treatment of tuberculous joint disease, although it is rarely necessary Amputation is indicated under 14 only when the patient does very badly under conservative measures and life is menaced, in young adults only when doing badly under conservative treatment or when the bone disease is too extreme for resection and bony ankylosis in older people in any case unsuitable for excision and fusion

Part 2

TUBERCULOSIS OF SPINE (POTT S DISEASE)

Tuberculosis of the spine or Pott s disease is the most common form of joint tuberculosis It comprises approximately 42 per cent of all cases and occurs most commonly in the first decade of life

Pathology

Some knowledge of the pathology of tuberculosis of the spine is necessary for an intelligent understanding of treatment The local pathology is a destructive process which involves the body of one or more vertebrae, the laminae, pedicles, and spinous processes are seldom affected About 50

per cent of the tuberculous lesions of the spine occur between the tenth dorsal and second lumbar vertebrae Destruction of the vertebral bodies always results in the formation of an abscess, made up of the debris of broken-down bone Such abscesses reach demonstrable size in approximately 20 per cent of all cases As destruction of

FIG 305 X ray of a tuberculous spine showing collapse of two vertebrae and development of a kyphosis

the bodies of the vertebrae advances, their strength is undermined so that finally one or more vertebrae collapse, and deformity in the form of kyphosis develops (Fig 305) As destruction and deformity increase, compression of the spinal cord may occur, and result in partial or complete paralysis of the legs, a condition known as Pott s paraplegia

TREATMENT

Since tuberculosis of the spine is a local manifestation of a constitutional disease, treatment, to be successful, must be both general and local General treatment has been thoroughly discussed in the section on General Principles of Treatment, p 368, and the reader is referred to that section for a description of the measures employed

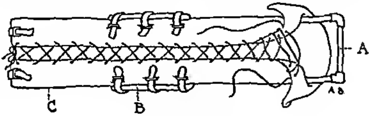
The purpose of treatment directed toward the local lesion is arrest or cure of the disease with a minimum of deformity In spinal tuberculosis this is accomplished only by bringing about solid bony ankylosis between the affected vertebrae This may be accomplished by (1) conservative or nonoperative treatment or (2) operative treatment

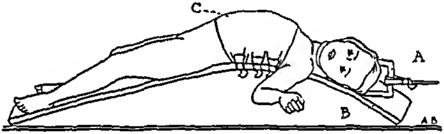
Before discussing in detail the nonoperative and operative treatment of spinal tuberculosis it is necessary to arrive at as clear an understanding as possible of what may be expected of each Such an understanding is necessary if an intelligent selection of the method to be followed is to be made Bony ankylosis of the involved vertebrae is brought about by conservative treatment in a definite percentage of cases To accomplish this as nearly absolute fixation of the spine as possible over a long period of time is necessary—three or four years, as a rule However, in a fairly high percentage of cases, even with such prolonged protection bony fusion does not occur, but a fibrous ankylosis results instead—a situation which is not a cure but merely a temporary arrest of the condition An adequate spinal fusion in which the uninvolved posterior parts of the vertebrae are firmly fused by operation, on the other hand, in the majority of cases, gives solid ankylosis of the diseased vertebrae in from two to three years Furthermore, fusion by operation cuts down the time during which the child is required to be hospitalized and under rigidly supervised treatment—a very important advantage

Based on the generally admitted facts that fusion of the spine by operation does result in a higher percentage of bony ankylosis, and that it materially reduces the

duration of treatment, spinal fusion must be considered to be the best method of combating the local disease in tuberculosis of the spine, and should be the method of choice This statement will not find universal endorsement but certainly it is the one most generally accepted at this time In our opinion there is one exception to maintained in hyperextension This can be accomplished effectively only on a Bradford frame or the Whitman modification of the Bradford frame or in a plaster shell

The Whitman modification of the Bradford frame is made of one inch gas pipe and is slightly broader than the patient and several inches longer The longitudinal bars





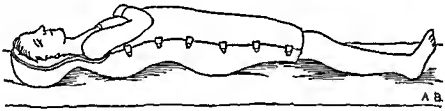


Fig 306 (*Top*) Whitman frame (A) Gas pipe frame (B) bib (C) laced canvas cover

Fig 307 (*Center*) Child on covered frame with head traction (A) Head traction (B) frame (C) bib or apron

Fig 308 (*Bottom*) Plaster shell applied in hyperextension skull included Shell bivalved for convenience in removing

this statement Tuberculous caries of the cervical spine should as a rule be treated by nonoperative methods

Nonoperative Treatment This follows three lines (1) Recumbency, (2) ambulation, and (3) convalescence

Recumbency Recumbency eliminates the stress upon the diseased vertebrae and fairly satisfactorily immobilizes the involved region of the spine Recumbency should be are bent at any point desired to produce hyperextension of the spine The frame is covered with a solid canvas, laced over the longitudinal bars (Fig 306) The patient is placed on the frame and fixed to it by a bib or shoulder straps attached to the longitudinal bars The child should not be permitted to sit up but should be *rolled on its side* for bath and alcohol rubs The frame permits free use of heliotherapy With in

volvement of the cervical spine, head traction should be added to the hyperextension (Fig 307)

A plaster shell is made by constructing a posterior plaster mold with the patient in hyperextension Hyperextension is necessary to throw the stress of weight on the un

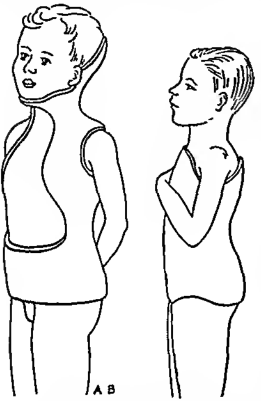


FIG 309 (*Left*) Calot jacket applied in hyperextension, including chest and occiput Extends to groin

FIG 310 (*Right*) Plaster jacket to be used when lesion is in lower dorsal or lumbar spine Extends from intercostal notch to groin

damaged posterior part of the vertebrae and to remove it from the damaged bodies The mold includes the posterior half of the skull if the disease is in the upper dorsal or cervical region and always extends down both legs to the knees A similar type of mold should be made for the anterior surface of the body (Fig 308) These combined molds, when fastened together, insure complete immobilization of the spine in hyperextension Half of the shell may be removed at a time for heliotherapy and for cleansing purposes. This is a very effective method of immobilization

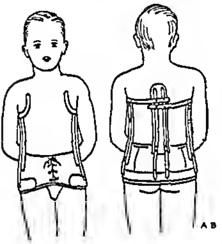
The period of recumbency on a frame or in a shell should last until roentgenographic evidence of new bone formation leading to bony ankylosis is unquestionably present. This requires recumbency for 16 to 30 months—sometimes longer When the x ray examination and the general condition of the patient indicate satisfactory progress, ambulatory treatment is instituted The period of ambulation should extend over at least two years, during which time the patient should be adequately supported by a brace or plaster jacket

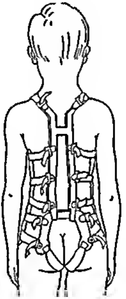
AMBULATORY JACKETS A plaster jacket rarely should be used unless there is involvement of the cervical or upper dorsal region, when plaster is the most efficient form of ambulatory fixation When applied for lesions of the cervical or upper dorsal spine, the jacket should be of the Calot type Such a jacket is applied with the spine in extension and under traction and extends from the groin to the chin in front and to the occiput behind (Fig 309) The jacket is cut out in front to allow free expansion of the chest in breathing When the lesion is in the lower dorsal or lumbar spine, the jacket should extend from the sternal notch to the symphysis pubis in order to hold the spine in hyperextension (Fig 310) The jacket should be carefully molded around the iliac crests to give firm fixation of the pelvis, since it is otherwise impossible to maintain hyperextension

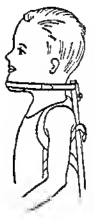
Ambulatory braces are preferable to jackets when an experienced bracemaker is available, as they are lighter and can be removed for heliotherapy and cleansing There is an infinite variety of spinal braces which can be used, most of which are efficient The function of a brace applied to immobilize and protect a tuberculous spine is to hold the spine in hyperextension and throw all the stress of weight bearing on

the undamaged posterior part of the vertebrae, thus relieving the collapsed bodies of as much of the superimposed weight as possible

To accomplish this, the pelvis must be firmly gripped by a pelvic band, and the shoulders must be drawn back so that the scapulae are pressed against the ribs with their vertebral borders parallel to the spine The pelvic band of the brace must be very shoulder strap fixation is usually undesirable, since, if the brace does not fit accurately or is carelessly applied, we find it suspended from the shoulders by the straps, thus adding the additional load of the weight of the brace to the spine we are attempting to protect A spinal brace should have two posterior upright and two lateral bars in addition to the pelvic band (Fig 311) The Taylor spinal brace which has







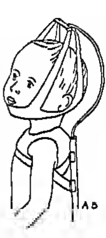


Fig 311 Fig 312 Fig 313 Fig 314

Fig 311 Spinal brace with double back bars, two side bars, and crutches Crutches designed to hold trunk in hyperextension, not intended to carry weight

Fig 312 Taylor spinal brace

Fig 313 *Occiput and chin support for Taylor spinal* brace

Fig 314 Head sling or jury mast for Taylor spinal brace

carefully fitted and must encircle the pelvis at the level of the prominence of the sacrum, not at the level of the iliac crests Unless the pelvic band is braced firmly against the sacrum, the spine cannot be immobilized The best method of holding the shoulders back is by crutches accurately fitted to make pressure against the front of the chest just below the coracoid process of the scapula (Fig 311)

Too many spinal braces rely upon some form of shoulder strap to maintain the hyperextended position and to hold the scapulae closely applied to the chest Such a special form of pelvic grip is a very efficient form of spinal support (Fig 312) When the disease involves the cervical spine, the head should be supported by a Taylor occiput and chin support (Fig 313), or a head sling on a jury mast (Fig 314) A brace is less effective than a plaster jacket in lesions of the cervical region

Convalescence The period of convalescence begins when bony ankylosis of the affected area is complete, as demonstrated by x ray, and when the general condition of the patient is satisfactory When the period of convalescence has been reached,

support should be gradually removed and increasing activity permitted The patient should remain under observation for a number of years any loss of weight, impairment of the general health or persistent back pain demands return to a rigid routine of treatment, for it indicates a lighting up of the old disease process

Operative Treatment This consists in creating solid bony bridges between the neural arches of the vertebrae thus firmly splinting the region of the spine attacked by the tuberculous lesion As a rule, two or three vertebrae above and below the involved area are fused The desirability of surgical fusion in adults is unquestioned There is some difference of opinion as to the advisability of surgical fusion in children Notwithstanding this difference of opinion there is in reality no valid reason why spinal fusion by operation may not be carried out at any age and there need be no hesitancy in performing such an operation on any child who has reached the age of three years Failure of operative fusion in young children may, as a rule, be attributed to an inadequate type of operation or to inadequate postoperative immobilization —not to inability of the child s spine to fuse Operative fusion, however, is only an aid in the cure of the local lesion, and affords no excuse for neglecting to use, in addition, everything of value in conservative treatment Stated in another way, operative fusion can give a maximum benefit only if preceded by a period of recumbency and general treatment sufficiently long to bring the individual s general condition up to a point where he can be looked upon as a good surgical risk, and only if followed by a period of fixation maintained by mechanical support until the diseased bodies show solid bony ankylosis by x ray This usually means two to three years

The operation itself carries with it the danger of shock If more than seven vertebrae are to be fused, it should be done in two stages While many advise the use of local anesthesia, it seems best in young children to use a carefully given general anesthesia and to have the child completely unaware of his surroundings It is worth while to secure as much correction of the deformity as possible before operation This is best accomplished by hyperextension on a frame for several weeks or longer The use of forcible correction to overcome deformity is never advisable

Broadly speaking, there are three methods of securing surgical fusion of the spine (1) The Albee method, (2) the Hibbs method, and (3) a combined method which uses some of the features of each of the other two

Albee Fusion technic (Fig 315) The tip of the spinous process of the involved vertebrae together with those of the three above and the three below are exposed through a slightly curved skin incision to one side of the midline The supraspinous and the interspinous ligaments are divided longitudinally down to bone The spinous processes are split into halves, the line of cleavage being carried well down toward the base of the spinous processes One half of each spine is fractured at its base and displaced laterally A graft taken from the tibia is then placed in the bed thus formed The graft taken from the tibia should be at least one half an inch in width and of sufficient length to extend two or three vertebrae above and below the diseased ones, and should include the full thickness of the cortex with as much cancellous bone as possible When the graft has been fixed securely in the prepared gutter made by splitting the spinous processes, it is held firmly in place by suturing the supraspinous ligaments, fascia and muscles over it If marked deformity is present, it is usually necessary to use a graft curved to fit the kyphosis, since a massive graft of the dimensions described is not flexible enough to bend sufficiently to fit the deformity If the graft is placed under too great pressure in an effort to make it con

form to the spinal deformity, it is apt to absorb at the point of greatest pressure. One method of meeting the problem of an acute kyphosis is to map out a curved graft of the desired shape on the anterior surface of the tibia, and, using a single blade saw, to cut out a shaped graft (Fig 316). In removing such a curved or shaped graft care must be taken not to include the crest of the tibia, as subsequent fracture of the tibia may occur Another very satisfactory method of meeting the problem is to cut from the tibia five or six grafts one-sixteenth to an eighth of an inch wide, placing these in the prepared bed so that they overlap. Such grafts are sufficiently flexible to conform to the curvature of the spine and will solidly unite.

The Hibbs Method: technic. The spinous processes of the vertebrae to be fused are exposed through a slightly curved skin incision lying to one side of the spinous processes. The intraspinous ligaments are divided longitudinally, and the tip of the spinous processes well exposed The periosteum is then reflected from the spinous processes and from the laminae outward to expose the articular facets of the vertebrae to be stabilized. The entire mass, composed of periosteum and muscles, is retracted laterally. The joints of the vertebrae to be stabilized are destroyed by curetting away their entire cartilaginous surfaces, proceeding systematically from one vertebra to another. Bone flaps are then gouged from the laminae and turned up and down, bridging the space between the laminae. The spinous processes are next broken down and

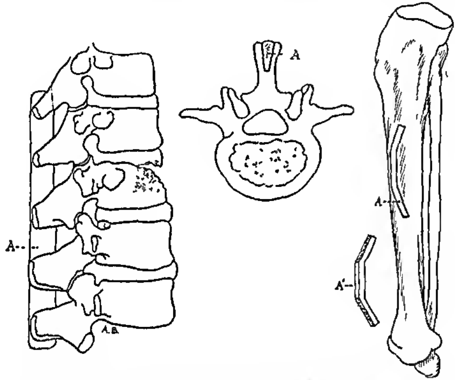
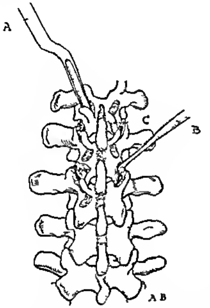


Fig. 315 (*Left* and *Center*) Schematic drawing of Albee operation for spinal fusion (A) Graft lying in bed, formed by splitting the spinous processes.

Fig. 316. (*Right*) Shaped graft removed from tibia (A) Graft. Note that crest should not be included as this weakens the bone and may result in a fracture

so arranged that the tip of the spinous process above rests on the base of the one below, or the spinous process may be split into several sections and turned up and down so that they interlace over the entire region to be stabilized (Fig 317) Such a stabilization has three points of fusion The articular facets the bone flaps between the laminae and the interlocking spinous processes The stripped back periosteum and muscles are then brought together and sutured forming a periosteal tube, surrounding the denuded area of bone

COMBINED METHOD TECHNIC Occasionally, with the Albee method, the graft will absorb between the spinous processes and with the Hibbs method sufficient ossification may not take place to insure as firm an ankylosis as is necessary To safeguard against these possibilities, a third method is very generally used which, on the whole, is probably more reliable than either of the other two This procedure carries out the Hibbs technic, and, in addition a massive graft or several small grafts, taken from the tibia are laid on the denuded laminae and in contact with the broken down spinous processes (Fig 318) The addition of an autogenous graft provides another source of bone proliferation and adds to the certainty of the fusion The closure is the same as in the Hibbs stabilization



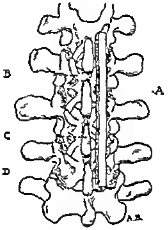


FIG 317 (*Left*) Schematic drawing of Hibbs spinal stabilization (A) Gouge turning down bone flaps from laminae (B) curette destroying articular facets (C) spinous processes fractured at base and turned down to be in contact with fractured base of spine below

FIG 318 (*Right*) Schematic drawing of combined method for spinal fusion (A) Graft from tibia lying on denuded laminae (B) bone flaps from laminae turned up and down (C) spinous processes fractured and turned down (D) destroyed articular facets

Fusion by the Albee technic requires less time than does a thoroughly carried out Hibbs procedure and there is less bleeding particularly if the plane of exposure in the Hibbs operation is not kept completely subperiosteal.

Because of these advantages, the Albee type of fusion should be used in very young children and when the general condition of the patient is not completely satisfactory The Hibbs operation must be very carefully done and consumes some time but theoretically at least it offers a more certain fusion The combined operation utilizes the best features of the other two and is the operation of choice except as indicated above

(See also Chapters 6, 7, and 9 for spinal fusion technic)

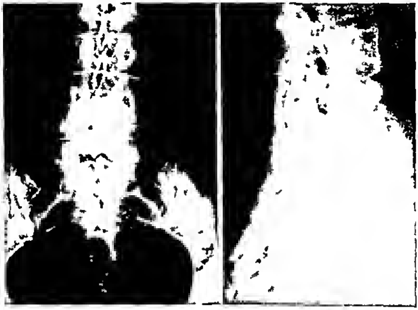


Fig 319 X ray of fused tuberculous spine showing satisfactory ankylosis of vertebral bodies (*Left*) Anterior posterior view, (*Right*) lateral view

After-treatment After treatment consists in the immediate application of a plaster jacket unless the patient shows signs of tiring or shock at the end of the operation when the application of the jacket may be postponed for a week or two, in the interim the patient being placed on a Bradford frame in slight hyperextension The immobilizing plaster jacket should extend from the sternal notch to the knees on both sides At the end of six weeks it may be removed and a new jacket applied, extending from the sternal notch to the symphysis pubis This jacket should remain on for three to six months, after which a brace may be used [The advice of this author in regard to postoperative immobilization following spinal fusion should be stressed There are too many pseudarthroses after spinal fusion which are to be attributed to inadequate postoperative immobilization The application of the jacket immediately postoperative, the inclusion of the hips and thighs in the original jacket, and the length of time during which plaster is worn are all of prime importance Postoperative treatment of spinal fusion cases by recumbency alone, or by recumbency plus a brace, is not a sound procedure —Ed] The patient may become ambulatory after two months following operation Support should be continued until solid ankylosis between the involved vertebrae and restoration of normal bony structure are evident in the x ray (Fig 319) This usually requires two years but may require longer Insistence upon support until solid ankylosis is shown

in the x ray is a safe rule to follow in every case of spinal fusion

Abscesses

A tuberculous abscess develops whenever extensive destruction of the vertebrae occurs As a rule, such abscesses are absorbed or calcified and require no treatment If, however, a tuberculous abscess does make its appearance on the surface, it should be treated conservatively and not opened unless absolutely necessary Above all, it should never be drained Introducing a drainage tube into a tuberculous abscess makes certain that a draining sinus will form, which will become secondarily infected and will probably never heal It has been truly said that draining a tuberculous abscess frequently signs the patient s death warrant A tuberculous abscess is a cold abscess made up of the debris of broken down bone, it does not contain true pus and, therefore, does not require drainage When a cold abscess approaches the surface and rupture through the skin seems inevitable, it should be aspirated, passing the needle through sound skin—not through the most prominent part of the abscess

If aspiration fails to control the abscess, it should be opened A small incision through sound skin placed at some distance from the most superficial point of the abscess should be used The abscess itself should be opened by blunt dissection, evacuated, and successively packed several times as tightly as possible with iodoform gauze this, as it is removed, will bring with it semi solid material contained in the abscess which can not drain out After scouring the cavity thoroughly with iodoform packing, all of which is immediately removed, the wound can be closed in layers, thus separating the abscess sac from the skin by as much sound tissue as possible If a cold abscess becomes secondarily infected, it must be opened and drained in

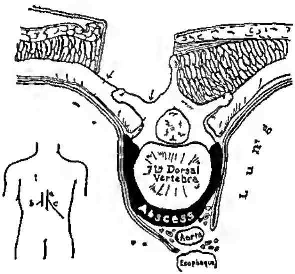


Fig 320 (*Left*) Incisions for drainage of tuberculous abscess pointing in cervical region

Fig 321 (*Right*) Costotransversectomy for drainage of tuberculous abscess of dorsal spine (a) Midline incision, (b) Bickham incision, (c) Kocher incision (Courtesy, Campbell W C Operative Orthopedics, St Louis, C V Mosby Co)

the same manner as any pyogenic abscess, this, however, is seldom necessary unless infection has been carried in, usually by efforts to aspirate. Needless to say, the opening of a tuberculous abscess should be performed under the most rigid aseptic technic.

The region of the spine involved determines where a tuberculous abscess will point. In the upper cervical region, it usually appears as a retropharyngeal abscess where it may cause serious interference with respiration or it may point in the posterior cervical triangle of the neck (Fig 320). In the lower cervical and upper thoracic region the abscess rarely points on the surface. Occasionally, it may enter the mediastinum causing pressure on the heart or lungs, and must be evacuated by a costotransversectomy resecting a portion of the rib adjacent to the spine (Fig 321). An abscess in the lumbar region usually follows down the sheath of the psoas muscle and points in the groin above or below the Poupart's ligament. It may, however, point posteriorly in Petit's triangle.

Treatment of Paralysis

Paraplegia, usually spastic though at times flaccid, may complicate tuberculosis of the spine occasionally. It is due, as a rule, to an inflammatory involvement of the meninges, a localized pachymeningitis; rarely is it the result of the deformity, although occasionally the acute knuckling of the spine is a factor. Ninety per cent of the cases in which paralysis occurs clear up with conservative management—absolute recumbency in hyperextension, preferably in a plaster bed. If, after some weeks of recumbency, there is no improvement, a hemilaminectomy may be done to relieve pressure. The results of a laminectomy, however, on the whole, are unsatisfactory, and our main reliance for securing relief must rest in conservative management, the laminectomy being resorted to only by virtue of necessity.

Part 3

TUBERCULOSIS OF SACRO ILIAC JOINT

The sacro iliac joint is seldom involved by tuberculous disease. When it is invaded, the prognosis is poor since the disease usually has extended widely before a diagnosis has been made. Involvement of the sacro iliac joint is rare in children and is essentially a disease of adult life.

Fig 322. X ray of tuberculosis of sacro iliac joint. Note area of destruction and decalcification in sacrum and ilium and loss of definition of joint line.

Pathology

The primary focus is usually in the sacrum, from which site it spreads to the ilium (Fig 322). As to whether the primary involvement is synovial or in the bone, there is as yet no accurate information. The course of the disease is essentially that of tuberculous infection elsewhere, namely, bone destruction, disintegration of the joint, and abscess formation. A cold abscess resulting from tuberculosis of the sacro iliac joint usually points anteriorly rather than posteriorly into the buttock,

and so extends into the pelvis and makes its appearance in the vicinity of the anterior superior spine or in the groin If the abscess points in the buttock, it usually reaches this position by passing out of the pelvis through the sacrosciatic notch A tuberculous abscess of the sacro iliac joint may rupture occasionally into the rectum

Treatment

The proper management of tuberculosis of the sacro-iliac joint must include general measures and those directed toward the cure of the local pathology General treatment has been thoroughly discussed on p 368 Local treatment may be (1) conservative or nonoperative or (2) operative

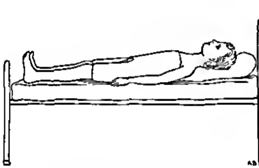


Fig 323 Double hip spica applied for tuberculosis of sacro iliac joint

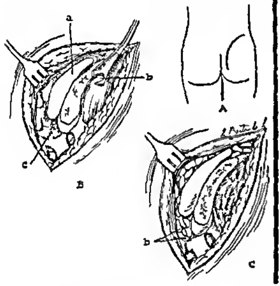
Before 1924, tuberculosis of the sacro iliac joint was looked upon as the most difficult form of tuberculous joint disease to treat successfully The reason for this lay in the fact that conservative treatment made little headway in stopping this disease Abscess formation, draining sinuses with secondary infection, and death were the usual sequelae Doubtless the difficulty of making a diagnosis before extensive destruction had occurred was to some extent responsible for the unfortunate results of conservative treatment, but the difficulty of satisfactorily immobilizing the joint was probably equally responsible With the advent of surgical fusion of the sacro-iliac joint the results of treatment materially improved, and today surgical fusion performed as soon as the diagnosis is made is the treatment which should be carried out Conservative treatment should be limited to the period of observation necessary to arrive at a diagnosis

Conservative Local Treatment This consists in securing as firm a fixation of the sacro-iliac joint as possible Such fixation is best secured by a double plaster spica extending from the nipple line to the knees (Fig 323) As stated above, such conservative treatment should be used only until the diagnosis has been definitely established

Operative Local Treatment Ankylosis of the sacro iliac joint is brought about by operative fusion This may be intra articular or extra articular in character The extra articular type of fusion is easier to carry out and may be used to advantage if a large abscess is not present If a large abscess is definitely present, the intra articular type of operation is to be preferred as the abscess will, as a rule unavoidably be entered and may be evacuated through the operative incision without jeopardizing the healing of the wound by first intention The following are the most commonly carried out fusion operations

Extra articular Fusion campbell technic (Fig 324) This is an extra articular arthrodesis of the sacro-iliac joint An incision is made along the outer lip of the crest of the ilium from the posterior one third or one half to the posterior inferior spinous process The soft structures are divided to the bone and subperiosteally elevated from the crest and upper portion of the dorsum of the ilium The erector spinae muscles are retracted toward the midline Beginning at the posterior superior spine and continuing around the crest of the ilium, a graft three fourths of an inch wide and three inches long, consisting of the full thickness of the ilium including the crest, is outlined by multiple cuts with a chisel, removed, and placed in a towel The inner table of the overhanging portion of the ilium and the adjacent posterior surface of

the sacrum is denuded Thus a gutter of cancellous bone is formed by the posterior surface of the sacrum and the inner surface of the ilium, posterior to and above the sacro iliac joint Into this gutter is inserted the graft from the crest The surrounding space is filled with multiple small grafts or shavings from the dorsum of the ilium The mass of bone is then impacted with a blunt instrument Closure is made by deep sutures through the fascia and muscles which exposing the lateral surface of the ilium In carrying out the dissection, one point should be kept in mind—the superior gluteal nerve and artery emerge at the anterior portion of the sacrosciatic notch and the vessels give off posterior branches which are encountered in the straight limb of the incision These sometimes cause considerable bleeding If the position of the sacro iliac joint is projected on the lateral surface of the ilium, it will be found that its inferior border cor



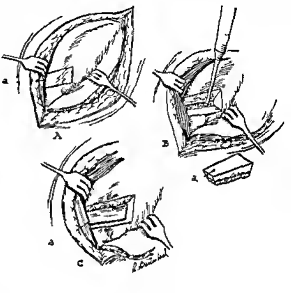


Fig 324 (*Left*) Campbell extra articular fusion of sacro iliac joint (A) Incision (B) (a) Large graft from crest of ilium (b) small grafts gouged from ilium (c) denuded surface of sacrum (C) Small grafts (b) packed about large graft and into space between ilium and sacrum

Fig 325 (*Right*) Smith Petersen method for intra articular fusion of sacro iliac joint (A) (a) Window outlined on surface of ilium (B) Block of bone (a) removed exposing cartilage of joint which is curetted away (C) Block of bone (a) reinserted in the bed and countersunk

when drawn firmly together hold the graft and bone chips firmly in place The rest of the wound is closed in layers

Intra articular Fusions smith petersen technic (Fig 325) An incision is made along the posterior two-thirds of the iliac crest, curving around the posterior superior spine and then continuing parallel to the fibers of the gluteal muscles, for a distance of two to three inches This incision is carried down to the bone, and the soft tissues are reflected subperiosteally, responds with the sacrosciatic notch and its anterior border with the median gluteal line The superior border is not of importance because the two landmarks given above determine the location of the joint adequately

A rectangular window is cut through the ilium within the projected area of the joint The thickness of the ilium above the sacrosciatic notch is considerable—sometimes as much as an inch—but if care is taken the entire block of bone, including the outer

ard the inner tables of the ilium may be removed in one piece When this window has been removed, the cartilaginous joint surface of the sacrum comes into view The cartilage of the sacrum as well as its cor the block of bone removed from the ilium this is inserted into the original site and countersunk so that its cancellous surface will be in contact with the cancellous bone of the sacrum The soft part flap is now re-

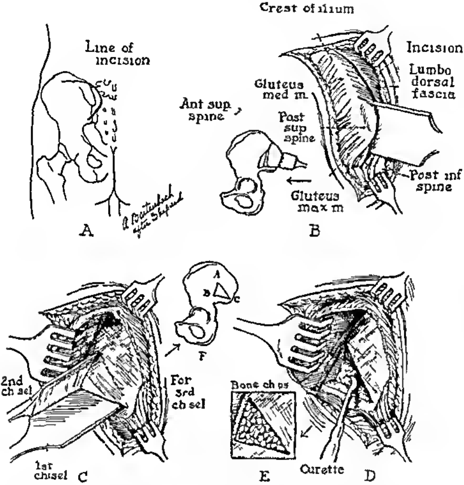


FIG 326 Gaenslen method of intra articular fusion of sacro-iliac joint (A) Incision (B) Bone flap being raised in sections as shown in insert (C) Flap retracted and area of sacro-iliac joint outlined along lines B—C and A—B as shown in insert (F) (D) Joint cartilages exposed by curetting down to joint, and removed (E) Bone which has been curetted out replaced after destroying joint

tex, is next removed, bringing about a good exposure of underlying cancellous bone The block procedure results in a rectangular box lined on all sides by cancellous bone, extending from the ilium through the sacro-iliac joint into the sacrum After the removal of the cartilage and cortex from placed and the periosteum and soft parts sutured in layers The position of the window cut may be varied Where an abscess is suspected the window should be cut in a direction parallel to the sacrosciatic notch which gives sufficient drainage of the joint

In the course of the procedure described

above, a curette should be freely used to reach parts of the joint not actually visible in the window made for the purpose of exposing the joint

F J GAENSLEN TECHNIC (Fig 326) F J Gaenslen has described a very satisfactory technic for arthrodesis of the sacro-iliac joint which differs somewhat from the method described by Smith Petersen

The patient should be placed in a semi prone position An incision is made along the posterior two thirds of the iliac crest, curving around behind the posterior superior spine and ending over the posterior inferior spine of the ilium This rather large incision is necessary to allow in a later step a proper reflection of a bone and soft part flap for intra articular work The wound margins should be freed and retracted sufficiently to well expose the crest to the posterior superior spine

After retracting the skin and fat flap an incision is made through the fascia and muscles over the posterior third of the crest and over the posterior superior spine, leaving a small margin of fascia and muscle on the outer lip of the crest to facilitate the fascial suture in closing The posterior portion of the ilium is now split flatwise with a broad chisel to a depth of two and one half inches forward from the posterior superior spine into an inner and outer leaf, the latter having the greater thickness It is very essential to have the plane of the joint and its relation to the normal bony landmarks well in mind However, with the chisel set against the posterior superior spine parallel with the plane of the posterior one third of the ilium and directed forward and slightly outward in the direction of the anterior superior spine of the same side, the ilium may be properly split In splitting it, the chisel is first centered over the posterior superior spine in the direction indicated above The split thus started is widened upward and downward to divide the entire posterior third of the ilium close down to the posterior inferior spine into two leaves, to a depth of one and one half inches When this depth has been reached, the external leaf should be broken free and retracted, as the curve of the ilium makes it impossible to split the ilium to the required depth in one unbroken leaf The remaining one inch of the posterior third of the ilium is then split with the chisel in smaller sections until the entire two and one half inch leaf is sufficiently freed to enable it with the attached gluteal muscles to be reflected readily, thus affording the necessary working space for exposure of the sacro iliac joint There is no danger in going too deep if the anterior superior spine is used as a landmark

The portion of the inner leaf overlying the joint is next attacked The sacro iliac joint is roughly triangular and, therefore, a triangular area of bone corresponding in size and location to the sacro iliac joint is marked out on the inner or standing leaf of the ilium and is removed The guide for marking out the triangle is as follows The base line, B — C, two inches long, extends forward from the posterior inferior spine directly toward the anterior superior spine on the same side The line B — A, one and one half inches long is erected almost perpendicularly from the anterior end of the first cut toward a point on the crest of the ilium representing the junction of the middle and posterior thirds The resulting angle of this cut will be slightly less than a right angle The points C — A are now joined with a third chisel cut, and the resulting triangle lies within the actual joint area and outlines the latter fairly accurately It is not necessary to remove this triangular area of bone in one piece It is better, in fact, to remove it in small pieces with a gouge or curette and to inspect the bone as one proceeds, saving the healthy portion for filling in the defect later Once the cartilaginous surface is identified in the center of the triangle, the entire joint is readily exposed Of the contiguous cartilaginous layers, that covering the sacrum

is much thicker The iliac portion of the cartilage is removed in fragments as the joint is uncovered with chisel and curette

FIG 327 X ray of a tuberculous sacro iliac joint after fusion by Gaenslen method Note firm fusion of joint with loss of joint line

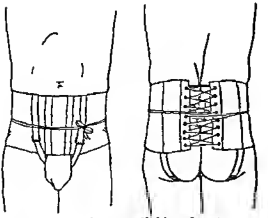


FIG 328 Anterior (*left*) and posterior (*right*) views of efficient sacro iliac support for use after fusion

The cartilage on the sacral face of the joint is similarly removed After the eradication of the joint in the manner indicated, healthy bone chips, removed during the course of the operation, are packed back very carefully and firmly to fill the gap completely The reflected outer leaf of the ilium is brought back into apposition and held in place by a few interrupted sutures through the dorsolumbar fascia and muscle The skin is closed as desired (Fig 327)

After treatment Following operation, whatever type of fusion is used, the patient should be immediately placed in a double plaster spica, which should extend from the nipple line to the knees on both sides This cast should be worn for at least eight weeks, preferably 12 weeks after which time a properly fitting sacro iliac support may be applied Such a sacro iliac support should be worn for at least three months longer (Fig 328)

Part 4

TUBERCULOSIS OF HIP (TUBERCULOUS COXITIS)

Involvement of the hip joint makes up about 30 per cent of all bone and joint tuberculosis About 85 to 90 per cent of the cases of hip-joint disease are found in children in the first decade of life

PATHOLOGY

The primary focus, when the hip joint is infected with tuberculosis, is, according to the studies of Hatcher and Phemister, found most frequently in (1) the neck of the femur, (2) the ilium, and (3) the ischium, in the order named (Fig 329) Primary synovial involvement probably occurs, according to the same authors, about as frequently as does primary involvement of the ilium No matter where the primary focus may be, the disease practically always extends into the hip joint and sets up a diffuse tuberculous arthritis with extensive destruction of the joint structures As destruction progresses, there is erosion of the femoral head and acetabulum and abscess formation (Fig 330)

Treatment

This must include general treatment and treatment directed toward eliminating active disease in the affected hip joint For a discussion of the general measures to be used, the reader is referred to the section on General Treatment, p 368 Local treatment may be (1) conservative or nonoperative or (2) operative

There are very definite criteria upon which the decision in favor of carrying out conservative treatment or of resorting to operative treatment may be based In the early stage of the disease, when there is no evidence by x ray of bone destruction, conservative treatment should be carried out, since there is a possibility that the joint may recover with normal free motion Such conservative treatment may be persisted in for from 18 months to two years, but if, at the end of this time, treatment has not resulted in a normally movable, pain free joint, it should be abandoned and the hip joint should be ankylosed by operation It cannot be anticipated that after this time such a joint will ever recover under conservative treatment, and the probabilities are that it will eventually reach the stage of fibrous ankylosis, a condition which cannot be considered safe or satisfactory from the viewpoint of useful function When, on the other hand, bone involvement and destruction of the joint structures are shown by x ray at the outset, recovery with motion cannot be expected, and bony ankylosis of the joint is the only result which can be considered satisfactory Such a joint may come to bony ankylosis under prolonged conservative treatment, but this is by no means certain, and as years will be required to accomplish this result a bony ankylosis brought about by a surgical operation is the treatment of choice

Nonoperative Local Treatment Nonoperative measures include traction and fixation to eliminate motion in the joint, and protection from weight bearing to avoid trauma to the diseased joint structures

Traction Traction should be used in the acute stage, which is characterized by acute joint pain, muscle spasm, and flexion de-

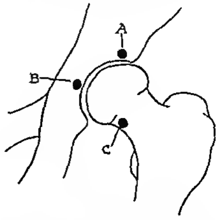


Fig 329 Points of origin of tuberculosis of hip (A) Ilium, (B) ischium, (C) neck of femur

Fig 330 X ray of a tuberculous hip Note erosion and deformity of femoral head and "wandering acetabulum"

formity of the hip joint Skin traction should be applied in the usual way, the adhesive bands extending from the upper third of the thigh to the ankle In order that traction may be effective, the patient must

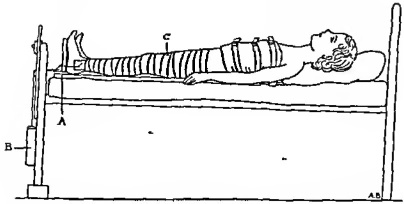


FIG 331 Method of applying traction for tuberculosis of hip (A) Bradford frame, (B) weight traction applied by Buck s extension, (C) note elevation of foot of bed for counter traction

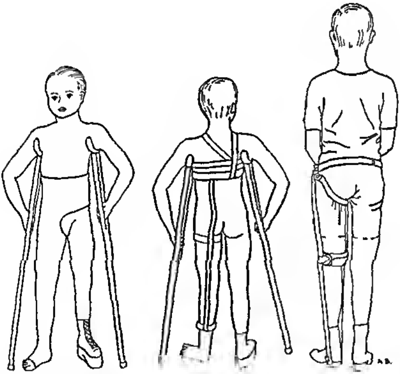


FIG 332 (*Left*) Spica applied for tuberculosis of hip High shoe on unaffected side and crutches for ambulation

FIG 333 (*Center*) Thomas hip splint for tuberculosis of hip

FIG 334 (*Right*) Walking caliper for tuberculosis of hip Note shaping of peroneal band which fits snugly about tuberosity of ischium to take weight of body comfortably

be placed upon a Bradford frame, which is an oblong frame of one inch gas pipe so constructed that it is a few inches wider and a little longer than the patient This frame is covered with a canvas, with an aperture in the region of the buttocks to facilitate the use of a bedpan (Fig 331) The patient is fastened to the frame by a bib attached to the frame Traction should be maintained until all pain is relieved, muscle spasm disappears, and the flexion deformity is corrected When, however, the joint has become quiescent fixation should be substituted for traction

Fixation Fixation is best obtained by the use of a plaster spica, extending from the nipple line to the ends of the toes on the affected side The spica should be applied with the extremity in about 20° of abduction and complete extension at the hip joint When the general condition of the patient is satisfactory ambulation in plaster may be permitted on crutches with an elevated shoe on the uninvolved extremity, so that the affected joint is protected from weight bearing (Fig 332) Plaster fixation should be maintained for at least one year At the end of this time a brace may be applied if the condition is progressing satisfactorily and the x ray examination shows that a bony ankylosis is taking place

Two types of brace are used The least complicated is that known as a Thomas hip splint This brace consists of a flat piece of malleable iron, three quarters of an inch wide and three sixteenths of an inch thick, long enough to extend from the angle of the scapula to the middle of the thigh, this forms the upright of the brace The upright is fitted to the contours of the back and buttock To this upright are attached chest, thigh, and leg bands molded to the contours of the chest, thigh, and leg The brace is thinly padded and provided with shoulder straps to support it and prevent it from slipping In addition, an elevation on the sound foot and crutches are used (Fig 333)

A walking-caliper type of brace may be employed This consists of a pelvic band with two uprights, the lower ends of which are made into a caliper which fits into the heel of the shoe The upright should be slightly longer than the length of the limb A Thomas peroneal ring connects the two uprights at the level of the tuberosity of the ischium This peroneal ring takes the major part of the body weight, which is short circuited around the hip joint It is essential that the ring sit in snugly well under the ischial tuberosity A slightly elevated shoe is worn on the unaffected side (Fig 334)

The walking brace should be worn for at least a year, and then, if the joint remains quiet, weight bearing may be permitted gradually However, it is best still to maintain elevation of the shoe on the unaffected side so that it will bear the major part of the weight The patient should be observed under weight bearing for at least three years If at any time, there is a recurrence of the active condition, the conservative treatment should be abandoned and a fusion operation performed

Operative Local Treatment The purpose of operative interference in tuberculous hip joint disease is to bring about bony ankylosis in the joint While there are still those who believe that conservative measures can result in a satisfactory cure of hip joint disease even with joint destruction, the most conservative feel that operative fusion is the better course, since it is more certain in its results and requires a less prolonged period of treatment A fusion operation may be done on any individual who has reached the age of four years The duration of the disease is unimportant except that the longer the duration and the greater the destruction, the greater the mechanical difficulty in performing a satisfactory operation Active disease does not contraindicate the operative fusion The presence of a draining sinus, while it complicates the procedure, does not contraindicate a fusion

operation A point of importance to be kept in mind is that a fusion does not interfere with the growth of the extremity unless the growth center has already been destroyed by the disease

It is not a simple matter to secure bony ankylosis in a joint infected with tuberculosis This fact is testified to by the variety of operations which have been devised in an attempt to make the results more certain Operations which aim at bringing about an arthrodesis or fusion of the hip joint are divided into (1) intra articular

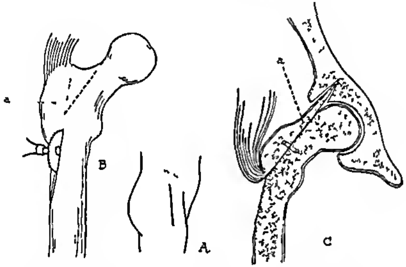


Fig 335 Hibbs fusion of hip joint (A) Skin incision (B) Removal of graft (a) from trochanter with muscle attachments intact (C) Cortex of neck removed and end of reversed graft (a′) inserted in slot in side of ilium

arthrodeses and (2) extra articular arthrodeses Attempts to produce arthrodesis by intra articular operations have been unsatisfactory in their results and have been largely abandoned The so-called extra articular fusion attempts to short-cut the diseased joint and secure an ankylosis between the trochanteric region of the femur and the side of the ilium without opening the joint capsule Except in early cases with little joint destruction it is generally impossible to do a purely extra articular fusion of the hip joint Most so-called extra articular fusions do enter the diseased joint, but do not aim deliberately to do so, nor is any of the diseased tissue in the joint removed as part of the procedure The most generally used types of fusion operation are the following

Hibbs Technic The Hibbs operation is not considered to be an extra articular type of hip-joint fusion (Fig 335) An incision is made beginning at the crest of the ilium, two inches posterior to the anterior superior spine This incision passes directly down to the trochanter and for three inches along the shaft of the femur The incision is deepened to the capsule of the hip joint by splitting the deep fascia, retracting the tensor fascia femoris laterally, and separating the fibers of the gluteus medius and minimus muscles by blunt dissection The periosteum of the femur is incised along the base of the trochanter and retracted medially The anterior three fourths of the trochanter and two inches of the cortex of the shaft below it is completely detached as a single piece with a chisel or saw, leaving the muscle and periosteal attachments intact The capsule of the joint is next split, the neck of the femur exposed, and the cortex removed from its superior aspect, leav-

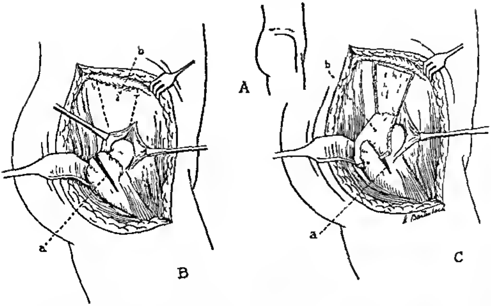


FIG. 336 J. C. Wilson fusion of hip joint (A) Skin incision. (B) Capsule split, neck and upper part of femur exposed, greater trochanter split (a), and graft (b), outlined on side of ilium. (C) (a) Split in greater trochanter into which is placed graft (b), turned down from side of ilium

ing a bed of cancellous bone exposed A portion of the thickness of the ilium, including the upper rim of the acetabulum, is then elevated to form a slot. The section of the trochanter and shaft which has been freed is then rotated on itself and its lower end introduced into the slot made in the ilium The remainder of the graft and its upper end (now the lower end) are brought into close contact with the cancellous bone of the femoral neck and the base of the trochanter. The periosteum of the graft is sutured to that of the ilium above and the femur below. The wound is closed in layers The thigh is then brought to an angle of 160° (20°) in abduction, and into slight flexion. This position locks the graft firmly in place. A double plaster spica is applied in this position, as described below under After-treatment.

J. C. WILSON TECHNIC (Fig 336). The capsule of the hip joint is exposed through a liberal anterolateral incision. The muscular attachments to the greater trochanter are freed with a blunt dissector. The epiphysis of the trochanter must be destroyed by curetting if it has not ossified, because if it is cartilaginous it endangers the nutrition

FIG. 337. X-ray of hip after fusion by Wilson method. Note solid bony column, extending from trochanter to ilium.

of the bone flap The shaft of the femur should then be exposed for a distance of about 6 cm This will aid in the preparation of the trochanteric cleft. The joint capsule is then split on its superior aspect and the anterior superior attachment to the ilium freed and well retracted The greater trochanter is then split for a distance of about 5 cm in the sagittal axis of the femur A very thin osteotome is used to reflect a fan-shaped section of the outer portion of the ilium after subperiosteal reflection of the gluteus from this region, the base of the fan, just above the margin of the acetabulum, being left uncut to form a pedicle By exercising a little caution the bone flap

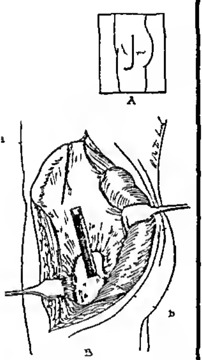


Fig 338

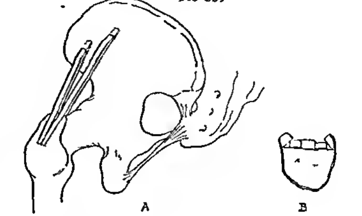


Fig 339

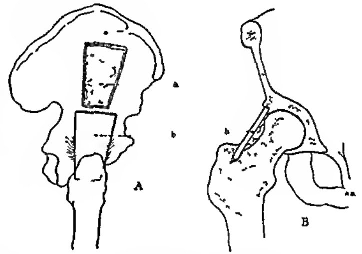


Fig 340

Fig 338 Ghormley type of hip fusion (A) Incision (B) Hip joint exposed—(a) graft cut from crest of ilium, (b) slot cut in trochanter, neck of femur, and upper rim of acetabulum into which graft is placed

Fig 339 Albee method for fusion of hip (A) Graft in place (B) Method of attaching grafts to trochanter (Courtesy, Albee, F H Injuries and Diseases of the Hip, New York, Paul B Hoeber, Inc)

Fig 340 Henderson method for fusion of hip (A) Graft (b) cut from lateral surface of ilium (a), embedded in trochanter and side of ilium. (B) Lateral view showing position of graft (b)

may be turned into the trochanteric cleft by bending the pedicle. This is especially true in children where the bones are very flexible and not easily broken A greenstick fracture of the flap happens occasionally, but the blood supply is not necessarily interrupted Since the periosteum of the ilium is removed with the gluteal muscles, replacement of the muscle flap brings the periosteum and fresh bone into contact A solid pyramidal section of bone is the result, the neck of the femur forming the base (Fig 337) After closure of the wound, the patient is placed in a previously prepared, well dried, warm, bivalved, long double spica as described below

Ghormley Technic (Fig 338) The incision begins on the crest of the ilium, three and one half inches posterior to the anterior superior spine, and extends downward below the tip of the trochanter and then is curved forward to a point four to six inches below the anterior superior spine The flap thus created is turned forward toward the midline Exposure is effected by severing the muscle attachments to the wing of the ilium and subperiosteally stripping the gluteus medius and minimus muscles from the crest A graft approximately three and one half inches long, consisting of the crest of the ilium including the anterior superior spine, is removed The capsule is incised on the superior aspect from the acetabulum to the trochanter A groove is then made from the upper rim of the acetabulum across the upper surface of the head, neck, and trochanter The graft is beveled and impacted into this groove

There are several other procedures of merit used in ankylosing the hip in joint tuberculosis Among these is that of Albee, who uses two free grafts from the tibia embedded in an indentation in the ilium above and into clefts made in the trochanter below (Fig 339) This is entirely an extra articular type of fusion and has given very successful results.

The operation of Henderson has also been extensively used, but it does not seem to offer any particular advantage over those already described, which are technically and physiologically sound and meet the requirements for a successful fusion if properly performed (Fig 340)

[For other technics for hip fusion, see Chapters 7 and 15 —Ed]

After treatment The hip should be immobilized in a double plaster spica in a position of 15 to 20° of flexion and at about an angle of 160° (20°) in abduction, mid

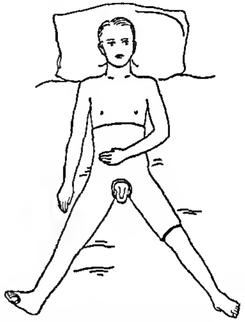


Fig 341 Double hip spica for post operative immobilization of hip

way between internal and external rotation (Fig 341) In children, because of the tendency for flexion deformity to develop even after fusion, the hip should be placed in full extension at an angle of about 160° in abduction (20°) The double spica should extend from the nipple line to the ends of the toes on the affected side and to just above the knee on the opposite side This form of fixation should be maintained for at least two months or until union is clinically present A single plaster spica may then be applied, extending from the nipple line to the ends of the toes on the involved side and

the child allowed to become ambulatory on crutches with a high sole on the shoe on the unaffected side, and without weight bearing on the affected side (Fig 332) This type of fixation should be continued for two months longer At the end of this four month period, increasing weight bearing may be permitted, the hip joint being protected by a short plaster spica or some form of protective brace, the former being preferable In adults, union is usually firm in four to six months—in children it may require eight months for fusion to become firm All cases—adults or children—should remain under supervision for several years For reasons already given, general measures designed to maintain the individual's general condition at its best should be insisted upon as long as the patient is under observation Such general measures include avoidance of fatigue, plenty of fresh air and sunlight, and an adequate diet

Amputation

Amputation for tuberculosis of the hip is seldom indicated Amputation should be resorted to only in those cases growing progressively worse under treatment and in whom the x ray shows extensive destruction Under such conditions, amputation is indicated as a life saving measure (See Amputations and Prostheses, Chapter 19, for procedures)

Abscess

A tuberculous abscess which develops in the course of hip-joint disease should be treated conservatively If the abscess approaches the surface, it may be aspirated When aspiration fails, it should be incised through sound skin, the incision being placed as far as possible from the most superficial point of the abscess After the abscess has been evacuated, it should be closed in layers with as much tissue as possible placed between the abscess and the surface A drainage tube should never be introduced into a tuberculous abscess unless it has become secondarily infected Most tuberculous abscesses of the hip which reach large size unfortunately tend to break down and form draining sinuses

A tuberculous hip joint infection complicated by one or more chronically discharging sinuses presents a definite problem in management. As previously stated, draining sinuses, unless they are too extensive, are not a contraindication to fusion, and frequently a successful fusion operation results in the closure of such sinuses When a fusion operation is contraindicated because of unfavorable local or systemic causes, immobilization by a plaster spica in which a trap door is made for dressings, and general measures directed toward building up the general health and improving resistance, are the best methods of quieting down the local condition so that fusion may be carried out later

Part 5

TUBERCULOSIS OF KNEE

Tuberculosis of the knee ranks next in frequency to tuberculosis of the hip About 80 per cent of the cases occur in the first decade of life

Pathology

In tuberculosis of the knee joint, the primary focus of infection may be in the synovia or in the bone on one or both sides of the epiphyseal cartilage The site of the primary bone invasion may be either in the upper end of the tibia or the lower end of the femur Synovial tuberculosis is more common in the knee joint than in other joints, or else the diagnosis is made earlier and before bone involvement which is radiologically demonstrable occurs This fact is of some importance in treatment From the primary site of invasion, the disease extends into the joint, causing destruction of joint structures and disintegration of the joint (Fig 342) Abscess formation occurs in about one-third of the cases

Treatment

As in all tuberculous joint infection both general and local treatment is indicated General treatment includes the employment of all the accepted means for improving health and building up resistance and is discussed in detail on p 368 Local treatment may be (1) conservative or non operative or (2) operative result which can be considered safe Synovial tuberculosis in children does heal in a fair percentage of cases with free movement and in children conservative treatment should be given a fair trial when carefully made x rays do not reveal a bony focus When bone involvement and joint destruc

Fig 342 X ray showing tuberculosis of knee Note decalcification of lower end of femur and upper end of tibia beginning erosion of joint cartilage and increased joint space

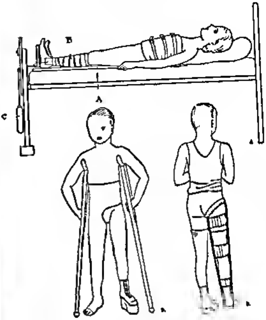


Fig 343 (*Top*) Application of traction in tuberculosis of knee (A) Bradford frame (B) traction applied below knee and (C) weight

Fig 344 (*Bottom left*) Application of plaster spica for tuberculosis of knee For ambulation crutches and high shoe on unaffected side

Fig 345 (*Bottom right*) Walking caliper for ambulatory treatment of tuberculosis of knee Note peroneal hand fitting snugly against tuberosity of ischium to carry weight and elevated heel of shoe on uninvolved side

It should be recognized that there are only two safe end results in tuberculosis of the knee—free and painless movement or bony ankylosis Recovery with free motion is possible only if the infection is confined to the synovia When bone involvement is present serious and permanent damage to the joint has occurred Recovery with a useful joint under such conditions is impossible and firm bony ankylosis is the only tion are shown in the x ray, free motion and a satisfactorily healed lesion cannot be anticipated in children or in adults and ankylosis by operation is definitely indicated In children however conservative treatment should be carried out until the child has reached a fusion age The lower age limit for fusion is from six to eight years Many are of the opinion that fusion should not be attempted until the age of

10 to 12 years has been reached. This opinion is ultraconservative, however, as bony ankylosis will occur as early as six years without growth disturbance, provided the fusion operation is adequate and is carefully performed to avoid damage to the epiphyseal cartilage.

by operation in adolescents and adults following a preliminary period of conservative treatment, and in children without any evident bony focus when conservative treatment has been faithfully carried out and the patient has passed the age of puberty without the promise of free movement.

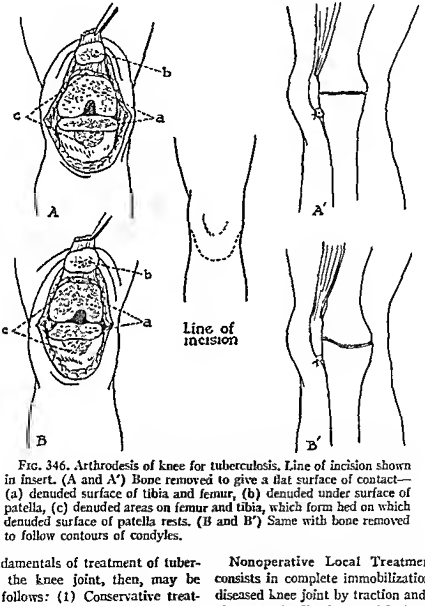


Fig. 346. Arthrodesis of knee for tuberculosis. Line of incision shown in insert. (A and A′) Bone removed to give a flat surface of contact—(a) denuded surface of tibia and femur, (b) denuded under surface of patella, (c) denuded areas on femur and tibia, which form bed on which denuded surface of patella rests. (B and B′) Same with bone removed to follow contours of condyles.

The fundamentals of treatment of tuberculosis of the knee joint, then, may be stated as follows: (1) Conservative treatment in children without any evidence of an osseous focus and those with evident bony involvement until the age of six to eight years has been reached; (2) fusion

Nonoperative Local Treatment. This consists in complete immobilization of the diseased knee joint by traction and circular plaster, and relief from weight-bearing.

Traction. When the disease in the knee joint is acutely active with pain, swelling, and flexion deformity, traction should be

applied and continued until these acute symptoms subside Adhesive traction is ap plied extending from just below the knee joint Anchoring the patient on a Bradford frame is an essential part of effective trac tion treatment in tuberculosis of the knee (Fig 343) When the acute phase of the disease has passed, fixation should replace traction as the immobilizing agent

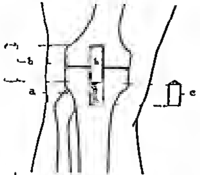
Plaster Immobilization Immobiliza tion with plaster is the most effective form of fixation in tuberculosis of the knee In order completely to immobilize the knee, a plaster spica should be applied, extending from the pelvis to the ends of the toes (Fig 344) In children the knee should be fixed in complete extension—in adults in 10° of flexion Such fixation should be maintained for approximately a year The major part of the time the patient may be ambulatory on crutches with an elevated sole on the shoe on the sound foot and without weight bearing on the involved side Following such a period of immobili zation by plaster, if the general condition is satisfactory and the local disease has quieted down, a walking caliper should be applied and worn for from one to two years or longer (Fig 345) Such long periods of immobilization may be carried out without fear of ankylosis because long immobiliza tion does not lead to fixation Loss of motion *is due to disease* If there is a recrudes cence of the disease after two years of conservative treatment, such treatment should be abandoned as soon as the child has reached the fusion age, and the knee ankylosed by operation

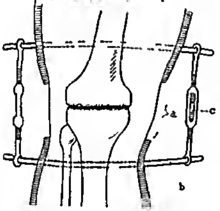
Operative Local Treatment Operative treatment in tuberculosis of the knee joint is designed to (1) promote bony ankylosis, (2) remove all diseased tissue which is ac cessible without either interfering with growth or lessening the prospect of bony ankylosis The latter objective requires that a complete synovectomy be carried out and all infected material be removed In other words, fusion of the knee joint should always be intra articular with the use of such extra articular aids as the operator may choose to add

Arthrodesis of Knee technic (Fig 346) A tourniquet is recommended, but it may be dispensed with [In knee joint operations where it is desirable to proceed without a tourniquet, troublesome bleeding may be largely minimized by the use of a high Trendelenburg position during opera tion established ten minutes before the incision is made, the patient being lowered to the horizontal before closing the wound so that final complete hemostasis can be assured —Ed] The joint is best approached through a U shaped incision It begins at the level of the internal femoral condyle curves downward across the knee below the patella and then upward to the opposite condyle The patellar tendon is cut across, and the flap consisting of the patellar tendon and the anterior capsule is turned upward A careful synovectomy should then be performed, the crucial ligaments being severed to permit free access to the entire joint The semilunar cartilages are removed Diseased cartilage with a thin layer of bone is then removed with a saw or gouge from the articular surfaces In removing the cartilage and bone, the normal contours of the condyles may be followed and the tuberosities of the tibia shaped to shallow sockets into which these condyles fit, using the bared tibial spine as a tongue to fit into the intracondylar notch Some prefer, how ever to saw the surfaces off transversely to form two flat planes If a valgus or varus deformity is present, the condyles should be shaped to overcome this deformity If flexion deformity has developed, sufficient bone must be resected to allow complete extension of the knee In children as little bone as possible should be removed to avoid interfering with the epiphyses and future growth

The under surface of the patella should next be denuded of its cartilage, and the anterior surface of the upper end of the

tibia and the lower end of the femur freshened to form a bed in which the patella will lie as a bone graft between these two bones when the operation is completed. Some operators prefer to excise the patella. There is no advantage in doing this, and if the patella is removed a possible source of bone proliferation which is quite useful as an aid in securing firm ankylosis is lost. After completing the denuding of the patella and the anterior surfaces of the tibia and femur, the denuded surfaces should be brought into exact apposition and the operation completed by suturing the patellar flap back into place under sufficient tension to keep the patella in close apposition with the tibia and femur. After the completion of the operation, a spica is applied, extending from the pelvis to the ends of the toes on the side which has been operated upon. In children, the knee should be placed in complete extension, since some flexion de-





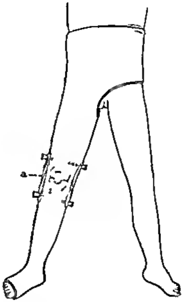


FIG 347 (*Left, top*) Schematic drawing showing reinforcement of arthrodesis by using a triangular graft from upper surface of tibia (a) Area from which graft has been removed from tibia (b) graft from tibia placed in groove in femur and tibia to bridge line of fusion (c) bone cut from femur to provide a groove for graft is placed in (a) to fill space in tibia left by moving graft upward

FIG 348 (*Left, bottom*) Key's method of maintaining close apposition of denuded bone surfaces by Steinmann pins through tibia and femur and use of a turnbuckle. Section removed from plaster cast (a), to allow approximation by turnbuckle (c), attached to Steinmann pins (b)

FIG 349 (*Right*) Author's method of applying Key's method using two Steinmann pins and figure-of-eight turns of plaster (a) to draw pins together and maintain firm contact of denuded bone surfaces

formity will later develop In adults flexion at an angle of 160° is the most useful position for ankylosis

In adults the expectancy of securing a firm fusion may be enhanced by the use of a sliding triangular graft taken from the upper end of the tibia (Fig 347) To make such a graft, the upper end of the tibia is bared after exposure and synovectomy as above and a triangular graft is cut one half to three quarters of an inch wide and long enough to bridge the gap between the tibia and the femur A triangular groove of sufficient length to receive the upper end of the tibial graft is then cut in the internal condyle of the femur The triangular graft is then firmly impacted into the groove in the femur and tibia The triangular piece removed from the femur is inserted in the vacant space left in the tibia by sliding the graft upward Such a graft helps to give firm fixation and provides an additional source of ossification

It is important during healing that the bone surfaces be kept in close and intimate contact To accomplish this Albert Key has recommended that one stainless-steel pin (three-sixteenths of an inch in diameter for adults and five thirty seconds of an inch in diameter for children) be passed through the lower third of the femur well above the field of operation and another through the tibia below the condyles These pins are placed parallel to each other and at such distance apart that they may be fitted with an extended turnbuckle Following the application of the plaster from the pelvis to the toes a circular section is removed at the knee, and the turnbuckles are tightened to maintain firm contact of the bone ends The tightening is repeated as often as necessary, the degree of pressure being determined by the bend of the pin (Fig 348) The author has been impressed with the effectiveness of Key s procedure, since ankylosis seems to occur more rapidly and completely because of the close apposition of the bone ends thus maintained The danger of applying too much pressure with the turnbuckles, however, has called for a modification of Key s technic This consists in driving the pins as Key describes allowing the pins to project through the plaster, and, before the plaster is set making strong compression against the pins holding this compression by figure of eight turns of plaster running from the pin below on each side up and around the pin above on each side (Fig 349) This procedure produces a definitely impacting pressure and holds the bone surfaces in close apposition during the important eight weeks following operation At the same time it avoids the danger of making too much pressure as may occur with the turnbuckles This modification has worked very satisfactorily and allows the cast to be cut down to the level of the groin in eight weeks (Fig 350) [The increased rigidity of fixation secured by the use of the pins is as important perhaps as the element of pressure contact The success of the modification described by the author would seem to subscribe to this Movements of the bones at the fusion site are apt to

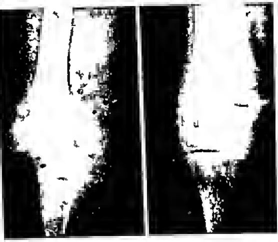


Fig 350 X ray showing complete bony fusion in two months following an arthrodesis and use of Steinmann pins and firm compression at site of fusion The author s modification was used in this case

lead to resorption of bone and therefore delay or prevent bony union —Ed]

A number of operators feel that fixing the tibia to the femur with wire nails driven through the tibia into the femur gives the most adequate fixation, and that such fixation is a useful adjunct to fusion operations There are also various types of bone grafts used to promote osteogenesis, such as those described by Henderson, Albee, and Putti (Fig 351)

After treatment The original plaster, with or without the pin modification, should be allowed to remain on for at least eight weeks At the end of this time it may be removed, with the pins if they have been used, and a close-fitting circular plaster, reaching from the groin to the ends of the toes may be applied (Fig 352) This should be worn for at least two months longer or until x ray examination shows that fusion is complete It is wise, even after the removal of plaster fixation at the end of four months, to apply a walking knee brace with a knee cap to be worn for another two months or longer, depending upon the density and apparent strength of the bony ankylosis (Fig 345) [For treatment of complicating abscesses, see p 380, this chapter —Ed]

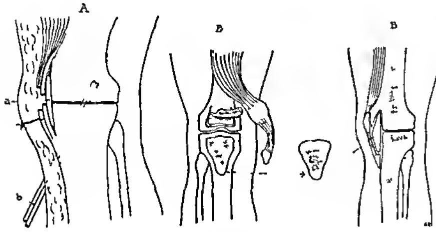


Fig 351

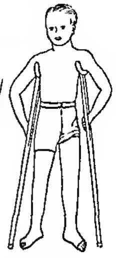


Fig 352

Fig 351 (A) Henderson method for fusion of knee for tuberculosis Articular surfaces of tibia and femur denuded patella (a) removed and trimmed and inserted under bone flaps turned up from anterior surface of tibia and femur Nails (b) are driven in obliquely through tibia and into femur, ends left projecting through skin

(B and B[1]) Putti method for fusion of knee A triangular graft is removed from upper anterior surface of tibia after detachment of patellar tendon This graft is reversed and its narrow ends are embedded in a slot cut in anterior surface of femur, its lower end is brought in contact with denuded surface of tibia Denuded under surface of patella is used to cover graft by resuturing patellar tendon to tibia (Redrawn from Campbell, W C Operative Orthopedics St Louis, C V Mosby Co)

Fig 352 Cast to be applied for convalescent care after arthrodesis of knee

Part 6

TUBERCULOSIS OF ANKLE AND FOOT

From 10 to 15 per cent of the tuberculosis of the lower extremities occurs in the ankle joint It is next in frequency to tuber

culosis of the spine, hip, and knee It is more common in children than in adults

Pathology

The primary lesion in tuberculosis of the ankle and foot may be in synovia or in bone When the primary involvement is in the bone *the astragalus is most commonly* invaded Next in frequency is the os calcis and then the lower end of the tibia Occasionally the disease may originate in one of the tarsal bones other than those mentioned such as the scaphoid cuboid or one of the metatarsals The first metatarsal is the most commonly involved of the metatarsal bones When the disease originates below the ankle *joint it shows considerable tendency to* spread and gradually involves both the tarsus and the metatarsus (Fig 353) Tuberculous disease of the ankle and foot, a destructive process eventually leads to abscess formation and such abscesses may rupture and produce draining sinuses

Treatment

The treatment of tuberculosis of the ankle and foot includes both general measures and treatment directed toward the elimination of the local disease General treatment is described on p 368 Local treatment may be (1) conservative or non operative or (2) operative

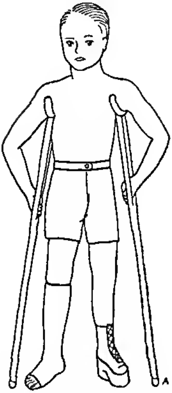
Tuberculosis of the ankle and foot can be considered to be healed only if there is recovery with normal motion or with firm, bony ankylosis between the involved bones Recovery with normal motion can be expected only if there is no bone involvement or destruction—in other words only when the involvement is confined to the synovia Once there is osseus *invasion and actual* joint destruction solid bony ankylosis is the *only outcome which is safe or which* will permit normal weight bearing There are however two other alternatives to bony arthrodesis—resection of a single bone which is involved or amputation Amputation is more commonly performed for tuberculosis of the ankle *and foot than for any* other joint Conservative treatment is indicated in pure synovial involvement in children up to the age of six to eight years Operative treatment should be carried out in adolescents and adults and in children over the age of six years who show evidence

Fig 353 *X ray of tuberculosis of foot* and ankle Decalcification of tarsal bones and bases of metatarsal bones with loss of outline and collapse of bones is plainly evident

of bone involvement unless conservative measures are leading to firm bony ankylosis *Operative treatment is also indicated in* children without evidence of osseus involvement who have had adequate conservative treatment and who have passed the age of puberty without the promise of free movement

Nonoperative Local Treatment This consists of complete immobilization of the

diseased joint and complete relief from weight bearing Immobilization is best secured by a plaster encasement extending from just below the knee to the ends of the toes Relief from weight bearing is secured by the use of crutches and an elevation on the sole of the shoe on the sound foot (Fig 354) Various devices are used to permit least another year (Fig 345) All cases of tuberculosis of the ankle and foot should remain under supervision for several years If there are any signs of recurrence of the disease rigid treatment should be resumed and when the individual has reached a suitable age the involved joint or joints should be ankylosed by a fusion operation



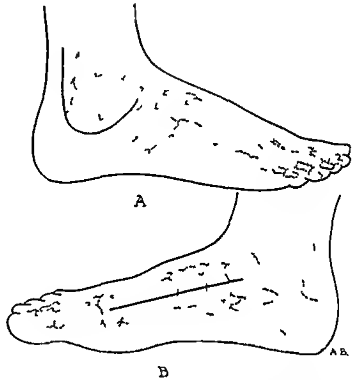


Fig 354 (*Left*) Cast applied for tuberculosis of ankle Cast extends from ends of toes to just above knee Elevated shoe on sound foot

Fig 355 (*Right*) (A) Curved incision passing around external malleolus for excision of astragalus or cuboid bone (B) Incision placed over scaphoid internal cuneiform and first metatarsal bones for excision of one or all of these bones

ambulation without crutches such as placing on the affected leg a walking stirrup embedded in the circular plaster Immobilization in plaster must be maintained for at least 12 months and usually longer When the joint has become completely quiescent or the x ray examination indicates that bony ankylosis is occurring gradual weight bearing may be permitted using a walking caliper brace to protect the ankle for at

Operative Local Treatment In the ankle and foot this includes resection of single bones fusion and amputation

Excision of Single Bones At times tuberculous disease of the ankle is confined to a single bone Such a single diseased bone may be excised and primary and complete healing may result (Fig 355) If there are draining sinuses the result is far less promising although healing does occur under

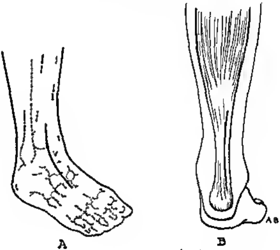
such circumstances If, however, several bones of the foot are involved, the excision will probably not be followed by success, and in children conservative measures are safer than resection Curetting is valueless Any bone involved must be excised en masse *Later reconstruction operations* may be necessary to bring about proper alignment of the foot (See section on reconstructions of foot after poliomyelitis Chapter 7)

FUSION OPERATIONS Fusion operations on the ankle may be intra articular or extra articular

EXTRA ARTICULAR FUSION This may be accomplished by an anterior approach or a posterior approach Campbell has described a very useful posterior approach, which has a distinct advantage in that it exposes both the ankle joint and the subtalar joint, which is intimately connected with the ankle joint and may be involved in the tuberculous process (Fig 356)

Campbell Technic An incision three inches in length is made over the posterior aspect of the ankle joint medial to, and parallel with, the tendo achillis, and is carried down beside this structure to the posterior capsule The flexor hallucis longus tendon is retracted medially The posterior capsule is not incised By means of an osteotome, large flaps of bone are turned down from the posterior aspect of the tibia and upward from the superior surface of the os calcis, overlapping at the level of the ankle joint This provides a massive extra-articular bony bridge across the joint (Fig 357)

INTRA ARTICULAR FUSION *Technic* Intra-articular fusion may be performed as follows The joint is approached by a five inch anterior incision in the sagittal plane, dividing the skin and subcutaneous tissue and, more deeply, the transverse crural and cruciate ligaments (Fig 356 A) The extensor hallucis longus and the tibialis anticus tendons, together with the dorsalis pedis artery, veins, and deep peroneal nerve, are retracted medially, and the extensor digitorum longus tendon laterally The anterior lateral malleolar artery and vein are divided and ligated The periosteum over the tibial diaphysis is incised, but one should avoid stripping the periosteum over the epiphyseal cartilage The articular cartilage over the lower end of the tibia, external malleolus,



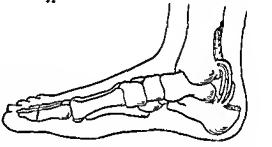


FIG 356 (*Top*) (A) Anterior approach for fusion of ankle joint (B) Posterior approach of Campbell for fusion of ankle joint

FIG 357 (*Bottom*) Extra articular fusion of ankle joint by method of Campbell

and the superior surface of the astragalus are completely removed together with all diseased tissues, and these denuded areas brought into close contact (Fig 358) It adds to the *efficiency* of the operation if, as recommended by Hibbs, through the same incision, bone is gouged from the lower end of the tibial diaphysis, well above the epiphyseal cartilages (children), and the small bone chips thus secured are wedged into the joint, to make firm bone contact

and to eliminate the dead spaces If the subtalar joint is involved, it should be denuded of its cartilage (inferior surface of the astragalus, superior surface of the os calcis, the head of the astragalus, and the proximal surface of the scaphoid) and the joint spaces completely eliminated In children in the growing period reinforcement of the fusion with a bone graft is contraindicated, since it would fuse the lower graft is applied over the ankle joint in contact with denuded tibia and astragalus

If a sliding graft is used, a full thickness cortical graft, one inch wide and two inches long, is removed from the tibia immediately above the joint surface A gutter of suitable dimensions is cut in the anterior portion of the body and the superior surface of the neck of the astragalus With the astragalus and the articular end of the tibia properly

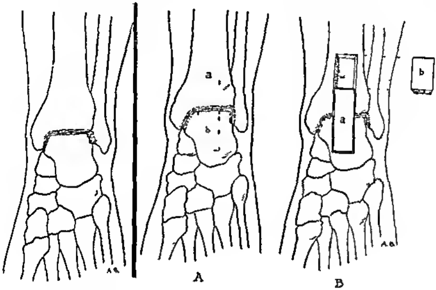


Fig 358 Fig 359

Fig 358 Schematic drawing of intra articular fusion of ankle Note area of denudation necessary

Fig 359 Intra articular fusion reinforced with sliding graft (A) Graft (a) outlined over lower end of tibia, (b) gutter outlined over astragalus (B) Graft (a), from tibia bridging ankle joint Bone (b) removed from astragalus may be placed above to fill gap in the tibia Such a graft may extend forward to cuneiform and cuboid bones if necessary

tibial epiphysis and interfere with bone growth In adults it is usually desirable to supplement the intra articular arthrodesis by a bone graft This may be an osteoperiosteal graft, a sliding onlay graft, or a transplanted graft

The osteoperiosteal graft is removed from the lower four inches of the exposed tibia with a chisel The superior surface of the neck and anterior portion of the body of the astragalus are next denuded and the aligned the sliding graft from the tibia is moved down across the joint, and its lower half countersunk in the gutter of the astragalus (Fig 359) The transplant graft is removed from another portion of the tibia and placed in a window of equal dimensions cut in the anterior aspects of the tibia and astragalus

If it is desired to ankylose the subtalar joint at the same time as the ankle joint, the graft should be continued down across

this joint extending into the scaphoid and cuboid bones With such a graft, an extra articular fusion of the subtalar joint is secured by fixing the astragalus to the cuboid and scaphoid, thus preventing any motion in the subtalar joint (Fig 360)

After treatment After the operation on the ankle has been completed it is immobilized in circular plaster extending from ankle is 10° of equinus, since this will permit the use of a moderately high heel (Fig 361) The original plaster should be changed at the end of two weeks and a snug fitting one with little or no padding applied Such a change of plaster enables a much better fitting one to be applied, allows the *equinus position* to be checked, and permits any desired alteration in the position of the

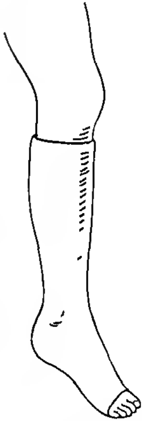


Fig 360 (*Left*) X ray of ankle fused with sliding graft Graft bridges ankle joint, extending forward to scaphoid bone thus fusing subtalar joint
Fig 361 (*Right*) Cast applied in 10° of equinus—the proper angle for fusion of ankle joint to permit comfortable walking following arthrodesis

the midthigh to the ends of the toes It is of paramount importance that the foot be placed in the proper position of equinus If there is too little equinus a stiff, peg legged gait will result If too much equinus is present, a halting awkward gait will result With the proper degree of equinus, the individual will walk with scarcely a perceptible limp The optimum position for the foot to be made Plaster fixation should be maintained until bony fusion is present by x ray This requires usually from three to six months

Amputation This is rarely indicated in children, but is advisable in adults when there is extensive involvement of the tarsal bones Such a type of involvement does not respond readily to conservative treatment,

and it is impossible to establish firm, bony ankylosis by any type of fusion operation In adolescents when several tarsal bones are involved and there are draining sinuses, amputation frequently is the proper course to take, since extension to other joints or a tuberculous meningitis will likely develop if the offending foot is not removed [For procedures and optimum levels, see Amputations and Prostheses, Chapter 19 For treatment of complicating abscesses, see p 380 —Ed]

head The synovia seems to be rarely involved primarily The most common form of tuberculosis of the shoulder is the so-called dry form, in which there is gradual destruction of the head of the humerus and replacement of bone and cartilage by granulation tissue There is gradual wearing away of the humeral head, which becomes deformed Eventually there is a flattening out of the glenoid fossa In this type there is little tendency to abscess formation, it is known as "caries sicca" (Fig 362) In the more unusual 'wet' form there is abscess formation, and a rather rapid destruction of the entire shoulder joint

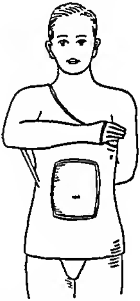


Fig 362 (*Left*) X ray showing tuberculosis sicca of shoulder joint Wearing away of head and flattening of glenoid are evident

Fig 363 (*Right*) Shoulder spica applied for tuberculosis of shoulder joint Spica is applied in from 50 to 75° of abduction and inclined somewhat forward

Part 7

TUBERCULOSIS OF SHOULDER

Tuberculosis of the upper extremity is uncommon compared to that of the lower extremity, and comprises only about 1 to 2 per cent of the tuberculous infections of the extremities Involvement of the shoulder is quite rare in children

Pathology

The primary focus of involvement is most commonly in the humerus, usually in the head ...

Treatment

As in all tuberculous conditions, treatment must include general measures to build up the general resistance and measures designed to care for the local disease General treatment is fully discussed on p 368, and need not be repeated here Local treatment may be (1) conservative or non operative or (2) operative

Tuberculosis of the shoulder, since it is usually primary in the bone, results in early joint destruction, and recovery with a movable joint is not to be anticipated. Bony ankylosis is the only outcome which can be considered safe or satisfactory. Bony ankylosis may be secured by conservative treatment through prolonged immobilization. However, the same result can be obtained by surgical fusion in a much shorter time and with much greater certainty. Ankylosis by a surgical operation, then, is the method of choice in the treatment of tuberculosis of the shoulder, particularly since it usually occurs in adults and the question of age does not enter the picture. Conservative treatment should be carried out only during the period required to arrive at a correct diagnosis, or during a stage of severe acute local and general manifestations.

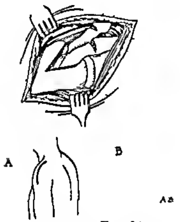


FIG 364

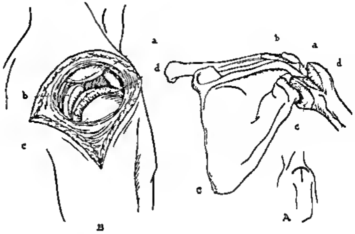


FIG 365

FIG 364 Watson Jones technic for fusion of shoulder (A) Incision (B) Superior and inferior surfaces of acromium are denuded, spine of scapula and clavicle are fractured and depressed acromium is embedded in notch made in greater tuberosity.

FIG 365 Intra and extra articular fusion according to technic of Gill (A) Line of incision (B) Denuded acromium (a) denuded glenoid (b) denuded head of humerus (c) cleft cut in greater tuberosity of humerus (d) (C) Manner in which denuded surfaces come in contact as arm is abducted.

Conservative Local Treatment Conservative treatment consists in immobilizing the shoulder in the optimum position for use. Immobilization is best secured by fixation in a plaster spica extending from the webs of the fingers to include the shoulder and the trunk down to below the iliac crests. The arm should be placed in 50 to 75° of abduction and inclined somewhat forward (Fig 363). If conservative treatment is to be followed throughout, such a cast must be worn for many months until the x ray shows good solid bony ankylosis of the shoulder joint.

Operative Local Treatment This consists in bringing about bony ankylosis of the shoulder joint by operation. Ankylosis of the shoulder may be secured by intra articular or extra articular fusion or by a combination of intra and extra articular fusion. It is difficult to bring about a bony ankylosis of the shoulder joint by a purely intra articular type of fusion and this type of operation has been practically abandoned. Extra articular fusion or a combination of intra and extra articular fusion gives the best results. The following are the types of operation most commonly used.

EXTRA ARTICULAR FUSIONS. WATSON

JONES TECHNIC (Fig 364) A vertical incision six inches in length is made on the lateral aspect of the shoulder, the center of the incision being over the acromioclavicular joint The upper third of the humerus, the outer third of the clavicle, the acromioclavicular area, and the outer third of the spine of the scapula are exposed by subperiosteal dissection The attachments of the deltoid to the clavicle acromion, and spine of the scapula are severed The superior and inferior surfaces of the acromion and clavicle are then denuded of cortex down to cancellous bone Beginning at the outer face of the upper end of the greater tuberosity of the humerus immediately beyond the capsular attachment, a broad osteotome is driven downward and a bone flap one inch wide and two inches long is wedged outward the base remaining intact The clavicle and spine of the scapula are fractured at their distal thirds and angulated downward permitting the acromion process and a portion of the clavicle to be wedged beneath the bone flap raised from the humerus when the arm is abducted If desired, bone chips or an osteoperiosteal graft taken from the tibia may supplement this procedure

INTRA ARTICULAR COMBINED WITH EXTRA ARTICULAR FUSION GILL TECHNIC (Fig 365) A dorsolateral semicircular incision is made across the shoulder, beginning one half inch below the acromion At the midpoint of the incision, a vertical cut is carried dowoward for a distance of two inches After proper exposure, the inferior and superior surfaces of the acromion are denuded, leaving the periosteum intact proximally The head of the humerus and the glenoid are then divested of articular cartilage, the humerus is split longitudinally, and the thio, outer, and anterior portion is reflected slightly outward A wedge of bone with its base upward is removed from the remaining inner portion of the head, forming a cleft into which the denuded acromion fits wheo the arm is in abduction The capsule which remains attached to the reflected anterior and outer osseus flap is sutured to the fascia and the periosteal flap on the superior surface of the acromion This is a combined type of intra and extra articular fusion

After treatment Following whatever form of fusion has been carried out, a plaster spica should be applied from the webs of the fingers to include the shoulder and the trunk as far down as the crest of the ilia (Fig 363) The shoulder should be placed in about 75° of abduction in adults and 90° of abduction in children in both the arm should be placed in about 45 to 60° of forward flexion The spica should be worn until there is unquestioned evidence by x ray of solid bony fusion The time needed for adequate bony fusion is from three to four months at a minimum

[For the treatment of complicating abscesses, see p 380 Other variations in technic for shoulder fusion are described in Chapters 7 and 15 —Ed]

Part 8

TUBERCULOSIS OF ELBOW

Tuberculosis of the elbow joint is not very common but is more frequent than tuberculosis of the shoulder It is more commonly met with in adults than in children

PATHOLOGY

It is generally considered that the primary focus in tuberculosis of the elbow is in the bone Most frequently the disease originates in the olecranon, and the next most frequent primary site is the external condyle of the humerus The head of the radius is rarely primarily involved However, primary synovial tuberculosis is probably more frequent than the records would indicate, and the failure to make an early diagnosis at this stage of the disease is responsible for the low incidence of reported cases of synovial tuberculosis of this joint The course of the disease is a general spread from the original focus to the entire joint with de

struction of the joint structures, eventual abscess formation, and the formation at times of a discharging sinus (Fig 366)

Treatment

The treatment of tuberculosis of the elbow must include both general measures designed to build up the general resistance and local measures to combat the local disease General treatment is discussed on p 368 Local treatment may be (1) conservative or nonoperative or (2) operative

If treatment is begun early recovery with a useful amount of function may be expected in children in a fair percentage of cases In these cases, then, conservative

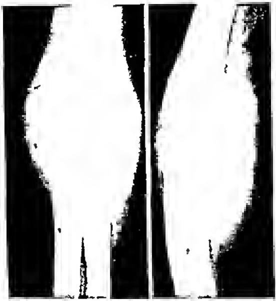


Fig 366 X ray of tuberculosis of elbow, anteroposterior (*left*) and lateral (*right*) views Decalcification, blurring of joint outline, and bone destruction without new bone formation are evident

treatment should be given a fair trial, and fusion by operation delayed until it is evident that recovery with useful function can not be anticipated When, however, a case is seen in which extensive joint destruction has taken place, time will be saved and a more certain result will be obtained by a surgical arthrodesis

Conservative Local Treatment This consists in complete immobilization of the elbow joint by a circular plaster, extending from the axilla to the wrist The elbow should be held in a position of 90° of flexion with the forearm midway between pronation and supination (*Fig* 367) Fixation

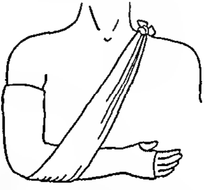


Fig 367 Plaster dressing applied for immobilization in tuberculosis of elbow Dressing extends from axilla to webs of fingers elbow in 90° of flexion and forearm in midpronation and supination

should be maintained for from 12 to 18 months If, at the end of such a period of immobilization a painless useful amount of motion is not present in the elbow joint, conservative treatment should be abandoned and ankylosis secured by a surgical operation

Operative Local Treatment The objective of operative treatment should be a firm bony ankylosis of the elbow joint Resection of the elbow in adults is widely advised and has given excellent results However, the danger of a flail elbow, which is much less useful than a stiff elbow in a useful position, makes this procedure less desirable than that of arthrodesis [A flail elbow may frequently be adequately stabilized by the use of a light weight brace consisting of laced leather cuffs about the upper and lower arms in which are incorporated side bars jointed at the elbow The leather cuffs should be molded to casts made of the parts,

and the side bars made to conform to their shape The side bars are best made of heavy spring steel rather than from the flat bars ordinarily used The frequent failure of such braces to give stability and their tendency to shift and slide is at least in part, due to the fact that they are ordinarily made with rigid bars and that the bars are made first and the cuffs then attached to the bars If the cuffs are made first and carefully molded on casts of the parts from not too flexible leather and the semiflexible spring steel

children Fusion, then in the author s opinion, is the method of choice when surgery is indicated Two types of fusion operation are in general use

Fusion of Elbow technic (Fig 368) The incision is made over the posterior aspect of the elbow centering over the tip of the olecranon and extending three inches distal and three inches proximal to this point Dissection is carried through the triceps muscle to the posterior surface of the humerus and the olecranon process

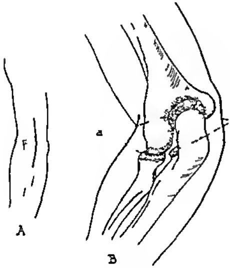


Fig 368

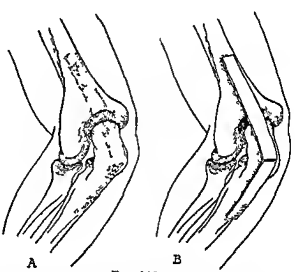


Fig 369

Fig 368 Fusion of elbow for tuberculosis (A) Line of incision, (B) denuded areas (a) lower end of humerus and head of radius (b) articular surface of upper end of ulna

Fig 369 Fusion of elbow (A) Same area denuded as in Fig 368 and in addition posterior surface of lower end of humerus and upper end of ulna denuded to provide a bed for osteoperiosteal graft (B) Osteoperiosteal graft in place

bars then accurately shaped to the cuffs, adequate stability without an annoying tendency for the brace to slip and shift can often be secured The proper type of brace may make it possible to secure a movable elbow which is stable after resection in those cases where the patient s livelihood or pleasure or contentment is dependent upon a reasonable range of painless motion at the elbow The ordinary brace is not satisfactory in most instances after elbow resection —Ed] Resection should never be done in

of the ulna The joint is opened, and the cartilage removed from the whole lower end of the humerus and from the upper ends of the radius and ulna As a rule ankylosis will occur following such denudation, if the bared bone surfaces are brought into firm contact and held there for three to four months

An additional aid to fusion is provided by adding an osteoperiosteal graft (Fig 369) When such a graft is used, the posterior surface of the lower end of the humerus and

the olecranon process of the ulna are denuded down to cancellous bone after the intra articular denudation has been accomplished An osteoperiosteal graft of suitable dimensions is taken from the tibia, and its osseus surface placed in firm contact with the denuded area of the humerus and olecranon The graft is held in place by the olecranon for a distance of about two and a half inches, with the periosteum and triceps tendon intact, is removed and reflected proximally, hinged on the triceps attachment A slot is next cut obliquely upward into the humerus at the upper border of the olecranon fossa The detached olecranon process is then mobilized, rotated

Fig 371

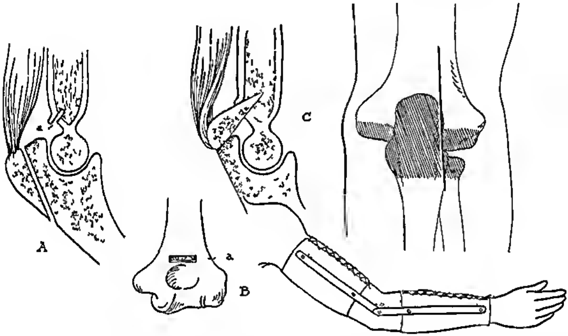


Fig 370 Fig 372

Fig 370 Hallock s technic for fusion of elbow (A) Section of olecranon with triceps attached removed and groove (a) cut in posterior surface of lower end of humerus (B) Slot (a) in lower end of humerus (C) Detached and rotated section of olecranon embedded in slot in humerus with its denuded surface in contact with denuded surface of remainder of olecranon (Redrawn from Jour Bone and Joint Surg , 14 145)

Fig 371 Schematic drawing of excision of elbow Line of incision shown in black line, area to be removed shown in shaded lines

Fig 372 Brace used following excision of elbow to provide stability and permit motion two cuffs, two side irons, and an elbow joint

suture to the adjacent periosteum and by firm closure of the wound

HALLOCK'S TECHNIC (Fig 370) With the patient in the prone position and the elbow in flexion, the joint is exposed through a dorsal midline incision After stripping the soft parts from both sides of the olecranon process and down the posterior border of the shaft of the ulna, the posterior half of through 180°, and the end forced into the slot in the humerus The distal portion of the graft lies in contact with the bared stump of the ulna If desired, a few bone chips may be placed along the line of contact with the ulna Chromic catgut sutures anchor the olecranon graft in place This is an attempt at extra articular fusion, although it is not really an extra articular

fusion as the joint cavity is entered No attempt, however, is made to remove the cartilage from the humerus and the upper end of the radius and ulna [For further discussion of elbow joint fusion, see Chapters 7 and 15 —Ed]

After treatment Following operation the elbow joint should be immobilized in a circular plaster extending from the axilla to the palm The elbow should be held in 90° of flexion and the forearm midway between pronation and supination At the end of two weeks the plaster may be removed, the stitches removed and a new and snugly fitting circular plaster applied with the elbow and forearm in the same positions Such fixation should be maintained for at least three to four months until x ray examination shows that bony ankylosis in the joint is established

Excision of Elbow Joint technic (Fig 371) A longitudinal incision is made over the posterior lateral aspect of the elbow extending from four inches above to at least two inches below the joint This incision is carried through the superficial tissues and fascia The triceps muscle is incised down to the humerus, parallel with the external border of its aponeurosis The posterior capsule of the elbow joint is then opened and stripping of the deep structures is carried on to bare the upper ends of the radius and ulna as far down as at least one inch below the head of the radius The periosteum and soft tissues are stripped from the lower extremity of the humerus and the bone divided just above the condyles, as much as possible of the metaphysis being left The upper ends of the ulna and radius are excised, as a rule, just below the level of the head of the radius, more extensive excision will result in a loose, flail joint The synovial membrane and all diseased tissue possible should be removed before the wound is closed

After treatment The arm is maintained in a right angle elbow splint for at least four weeks At the end of this time muscle education with active use should be instituted The result should be a reasonably serviceable elbow, although a rather unstable member results in the majority of cases If the joint is so unstable as to interfere with satisfactory use, the instability can be corrected by a brace consisting of a cuff for the arm and a cuff for the forearm with two side bars and a joint at the elbow (Fig 372) [See note on p 409, in regard to elbow braces —Ed]

Amputation

Amputation is rarely indicated in tuberculosis of the elbow joint Occasionally, in older individuals with extensive destruction of the joint and abscess formation, amputation must be resorted to On rare occasions cases are seen in children in which the disease has resulted in great destruction and numerous draining sinuses which make it impossible to do a fusion operation When such a condition exists, it is often wise to resort to amputation, but only after prolonged and careful conservative treatment has demonstrated that cure of the local disease in this way cannot be anticipated [For levels and procedure, see Amputations and Prostheses, Chapter 19 For treatment of complicating abscesses see p 380 —Ed]

Part 9

TUBERCULOSIS OF WRIST

Tuberculosis of the wrist is rather uncommon but in the author s experience it is more common than tuberculosis of either the shoulder or the elbow However, it is generally considered by most observers to occur less frequently than tuberculosis of the elbow It is more common in adults than in children

Pathology

The primary focus of tuberculosis of the wrist is usually in the lower end of the radius, but it may be in the carpal bones (Fig 373) The disease tends to spread rap-

idly and to involve the entire synovia of the wrist joint Abscess formation is not common in children In adults, however, abscess formation occurs early in the course of the disease and tends to invade the tendon sheaths and produce a complex ganglion of the wrist by working under the annular ligament and appearing in the lower part

treatment should be bony ankylosis Conservative measures in children as a rule, give bony ankylosis if persisted in for a sufficient length of time and should be the treatment of choice in those cases In adults conservative measures are not so successful, and ankylosis by surgical operation is definitely indicated

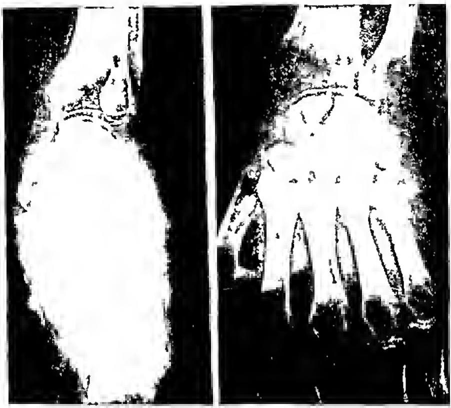


FIG 373 X ray of tuberculosis of wrist Decalcification loss of bone outline and loss of articular cartilage over lower end of radius and proximal row of bones are evident

of the forearm above the annular ligament as well as below it over the wrist and palm

TREATMENT

General measures to build up body resistance and local measures aimed at controlling the local disease are indicated General measures are discussed on p 368 Local measures may be (1) conservative or non operative or (2) operative

Tuberculosis of the wrist is rarely cured with a movable wrist, and the object of

Nonoperative Local Treatment This consists in complete immobilization of the wrist joint in a circular plaster This should extend from well above the elbow to the webs of the finger with the elbow at 90° of flexion and the forearm in the mid position between pronation and supination The wrist should be in 35° of dorsiflexion (Fig 374) Strict immobilization should be maintained for from 12 to 18 months If ankylosis is progressing satisfactorily at the end of this time, a cock up splint may be ap-

plied This should be worn for another six months or until ankylosis is complete as shown by x ray

Operative Local Treatment This may consist in excision of the carpal bones or a surgically produced ankylosis of the wrist joint In the author s opinion, fusion is to be preferred to excision as giving a more useful wrist and a more satisfactory result However excision is quite satisfactory in the adult if it is done early it should not be attempted if there is extensive destruction of the wrist joint It should never be done in children

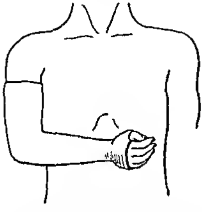


Fig 374 Plaster dressing for immobilization in tuberculosis of wrist Cast extends from upper part of arm to web of fingers with wrist in hyperextension and fore arm in midpronation

Fusion of Wrist technic (Fig 375) A posterolateral incision is made over the radius, extending three inches above the wrist joint and two inches below the wrist joint. The tendons of the extensor proprius indicis and the extensor pollicis longus muscles are separated and the joint and the lower extremity of the radius are exposed All diseased tissue and bone are removed from the affected area This may necessitate the excision of one or both rows of carpal bones Depending upon how much bone has been removed the articular surfaces of the distal row of carpal bones or the bases of the metacarpal bones are denuded of cartilage as are also the articular surfaces of the radius and ulna The denuded osseous

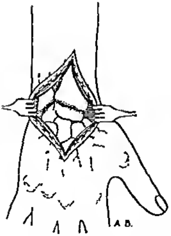
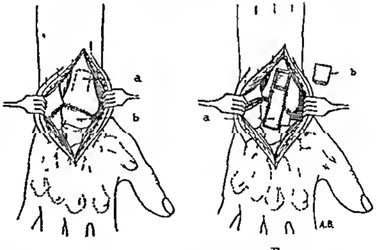


Fig 375



A B

Fig 376

Fig 375 Intra-articular fusion of wrist for tuberculosis Lower end of radius and ulna and proximal surfaces of scaphoid and semilunar bones are denuded

Fig 376 Intra articular fusion reinforced by bone graft (A) Bones of wrist denuded graft (a) outlined over lower end of radius and groove (b) over wrist bones (B) Graft (a) moved down into groove in wrist bones, bridging gap, bone (b) taken out to form groove in wrist used to replace bone taken from radius

surfaces are then brought into firm contact

As an additional aid to fusion, a sliding graft from the lower end of the radius may be used (Fig 376) When such a graft is used, it is cut from the dorsal surface of the lower end of the radius It should be of sufficient length to bridge the gap between the radius and the denuded carpal or metacarpal bones as the case may be The graft is slid down into firm contact with the dorsal surfaces of the carpal or metacarpal bones which have been denuded down to

removed, the stitches removed, and a new snugly fitting one applied This should be worn for from three to four months, or until bony ankylosis is evident by x ray (Fig 377) The plaster need not extend above the elbow after the first month and use of the fingers should be insisted upon after the first four weeks

Excision technic (Fig 378) A straight incision three inches long is made over the dorsal surface of the wrist in line with the ulnar border of the shaft of the radius

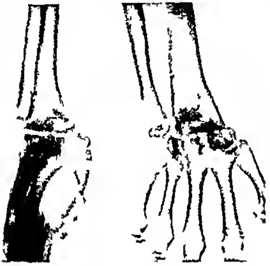


Fig 377

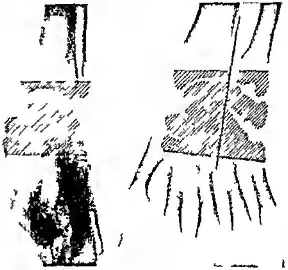


Fig 378

Fig 377 X ray showing fusion of wrist Proximal row of bones has been removed Fusion is firm

Fig 378 X ray showing excision of wrist Line of incision shown by black line Bone removed in shaded lines

cancellous bone This graft is held firmly in place by chromic catgut sutures and by firm closure of the wound An osteoperiosteal graft taken from the tibia may be used in place of the sliding graft from the radius if desired It is applied and held in the same manner

After care The wrist is immobilized in a circular plaster extending from well above the elbow to the webs of the fingers with the elbow at a right angle and the wrist in 35° of dorsiflexion and midway between pronation and supination The plaster is bivalved immediately to allow for postoperative reaction In two weeks it may be

Dissection is carried through the fascia and between the tendons of the extensor indicis proprius and the extensor longus pollicis down to the radius thence through the capsule of the wrist joint to the base of the second metacarpal bone The periosteum over the lower end of the radius and over the bases of the metacarpal bones is stripped away and the entire carpus and the triangular fibrocartilage are excised The articular surfaces of the radius and ulna are then removed down to normal appearing bone Occasionally, excision of one half inch of the metacarpal bones may be necessary

After care The wrist is immobilized in a cock up splint to maintain dorsiflexion until the immediate postoperative reaction has subsided Active exercise of the fingers is begun on the fourth or fifth postoperative day At the end of two weeks a plaster en casement is applied from the upper third of the arm to the heads of the metacarpal bones After three months, active exercise is instituted in the wrist, the wrist being supported between exercise periods by a leather wristlet This may be discarded in six months or worn indefinitely

[For treatment of complicating abscesses, see p 380 —Ed]

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15

Joint Infection and Arthritis (Except Tuberculosis)

J Albert Key, M D

Part 1 General

Treatment of Acute Pyogenic Arthritis The patient with acute pyogenic arthritis is ill with an acute infection and needs general treatment as well as treatment for the local joint disease The general treatment includes (1) sedation, which should be ample to enable the patient to get the required amount of rest, (2) the assurance of a sufficient fluid intake and the correction of any dehydration which may be present, (3) transfusion, if the red blood count has been depleted below about 4,000,000 and (4) chemotherapy

If the organism is known to be streptococcus, sulfanilamide in full doses should be given For an adult we usually give from 90 to 110 gr a day On the other hand, if the organism is unknown, it may be either a streptococcus or a staphylococcus, and for this reason sulfathiazole is the drug of choice For an adult we usually give an initial dose of 2 Gm, and this is followed by 1 Gm every four hours until the fever subsides The joint should be aspirated and the fluid examined for the determination of the type of pus, and a smear and culture should be made in order to determine the type of organism present

If a streptococcus is the offending organism, it may be worth while to treat the joint by the injection of a suspension of sulfanilamide, or of sulfathiazole directly into the joint after the fluid has been aspirated Since these drugs are relatively insoluble in water, the dry powder should be mixed with normal salt solution, drawn up into the syringe, and injected directly into the joint before it has an opportunity to settle out There need be little fear that the injection of this material will irreparably damage the joint structures, and in the case of streptococcus it is possible that it may sterilize the joint [See Chapter 22 for Chemotherapy, including the use of penicillin —Ed]

On the other hand, with a staphylococcus we believe that the joint should be opened as soon as the patient is thought to be in condition for the operation, that is, after the patient has been given an opportunity to rest if he enters the hospital in a state of exhaustion, and after his dehydration has been corrected, and usually after the chemotherapy has been given an opportunity to get into the system—that is, from six to 12 hours after admission The joint is opened, washed out with warm salt solution, and drained About 4 Gm of sulfanilamide or sulfathiazole powder are placed in the knee joint at the end of the operation In dealing with smaller joints less of the chemical is used In early pyogenic arthritis we have

left the joint cavity open after a relatively large amount of sulfathiazole has been placed in the cavity, but we have sutured the skin and obtained primary healing and satisfactory restoration of function

This method works well in the treatment of old chronic pyogenic infections of bones and joints where the infected tissues can be excised and the wound then closed with the sulfathiazole powder in the wound but its use in acute pyogenic arthritis is still in the experimental stage It is preceded and followed by full doses of the drug by mouth until the danger of the infection is past

After the operation the joint may be immobilized in traction or in a plaster of paris encasement, or the method of active movement of Wilms may be used If it is chosen to immobilize the joint in plaster or by traction it is usually immobilized in a position which will not greatly impair its function Traction is usually applied with the extremity in slight flexion or full extension, depending upon the joint If the Wilms' method of active movement is to be used, the extremity should be suspended in a splint in a position of full extension with moderate traction Every two hours, both day and night, once the patient has regained consciousness, the nurse should visit the patient and should lift up the traction weight and encourage the patient to flex the extremity The movement is carried through as wide a range as the patient is able to manage without undue pain After about 48 hours the patient is usually able to flex the extremity through quite a wide range of movement The limb is moved only a few times and the traction is then re applied until the end of the next two-hour period

It is to be noted that if the limb or joint is immobilized in plaster of paris, stiffening of the joint in a position of deformity in which the limb will be handicapped should be avoided For this reason the shoulder is usually immobilized in a position of moderate abduction (about 50°), the elbow in a position of moderate extension (about 120°), the wrist in a position of slight dorsal flexion, the metacarpophalangeal and interphalangeal joints in a position of slight flexion The hip is immobilized in a position of slight flexion and slight external rotation and it may be very slightly abducted or in the straight position The knee should be straight or very slightly flexed The ankle should be in a position of 90° dorsiflexion or in a position of slight plantar flexion (100 to 110°)

Treatment of Subacute Pyogenic Arthritis Including Gonorrheal Arthritis In this type of arthritis operation with drainage is not so urgent as in the true acute pyogenic arthritis In some of these joints, apparently due to low grade streptococci, the infection may clear up completely after immobilization and chemotherapy The same is true of gonorrheal arthritis Not only is gonorrheal arthritis affected by chemotherapy with sulfanilamide, sulfapyridine, or sulfathiazole when these are given in full doses, but it may also be promptly cured in most instances by adequate fever therapy Consequently, during recent years surgery has had a relatively small place in the treatment of either subacute pyogenic arthritis or gonorrheal arthritis, with the exception of immobilization of the joint in plaster of paris, or by traction, in a position in which deformity will be prevented, and for the comfort of the patient

Any acutely painful joint is rendered more comfortable when it is immobilized and the patient is given an opportunity to rest The immobilization also has a definite value in combating the infection The joint may be immobilized in a plaster-of paris encasement, in a splint, or by traction, as stated above under the treatment of acute pyogenic arthritis What was stated there concerning the prevention of deformities is also true of subacute arthritis

In certain instances in which the disease in one of these joints has progressed to a considerable degree, or in certain instances where the infection has refused to yield to

chemotherapy or to fever therapy, the joint may be opened through a small incision, washed out thoroughly with hot normal salt solution (115°) and then closed without drainage This method has, in the past, saved gonorrheal knees and other large joints from permanent destruction We now make it more effective by placing a relatively large amount of sulfanilamide or sulfathiazole powder in the joint before the wound is closed If the cartilage has been *destroyed by the infection, the joint will* probably become ankylosed by bone or by fibrous tissue and it is in these joints that arthroplasty has had its most useful application

In other instances the joints affected by either acute or chronic pyogenic arthritis or by gonorrheal arthritis have become ankylosed or stiffened in positions of deformity These deformities may be corrected by various methods depending upon whether or not the ankylosis is formed of bone The ankylosis if bony, is best corrected by osteotomy *if an arthroplasty is not indicated* On the other hand, if there is a fibrous ankylosis the deformity frequently can be corrected by wedging plaster of paris encasements or by skeletal traction or by forcible manipulation under general anesthesia

Treatment of Old Pyogenic and Subacute Arthritis These are joints in which the active infection apparently has subsided and which need treatment simply because of pain, or because of deformity, or because of stiffness If the joint needs treatment because of pain, this may frequently be relieved by strapping by elastic bandages, or by splints, and occasionally by a plaster of paris encasement which is applied with the joint in such a position that the maximum amount of function in the limb will be obtained if the joint should become ankylosed by bone The plaster eliminates movement, makes the patient comfortable, and prevents deformity If a deformity is present and is due to contracture of the soft tissues, it may be relieved by traction —with the patient in bed for lower extremity lesions, while for the upper extremity the patient is usually ambulant and fitted with some type of apparatus On the other hand, if the shoulder is glued to the side, the traction may be applied most conveniently with the patient in bed

In order to save time not infrequently these joints are manipulated under general anesthesia, care being taken, however, not to produce fractures by the manipulation For this reason an x ray of the bones of the joint is advisable before the manipulation is resorted to, and if marked atrophy of the bones is present the surgeon should be especially careful not to apply too much force otherwise, fractures are apt to occur

For the correction of deformities by traction, skeletal traction is as a rule more effective than is skin traction Not only is it more effective, but it is more comfortable to the patient [See Chapter 22 for technic and details of skeletal traction —Ed]

For the correction of a flexion deformity of the knee, double skeletal traction should be used one wire with a bow being passed through the proximal portion of the tibia, just below the insertion of the patellar tendon, and another through the distal portion of the tibia about two inches above the ankle joint The traction on the proximal wire is directed in line with the shaft of the femur while that on the distal wire is directed in line with the shaft of the tibia This permits the gradual correction of the flexion deformity and tends to prevent posterior subluxation at the knee

If the joints are ankylosed in a position of deformity by bone, these can be corrected by osteotomy The various operations are described in Part 2 of this chapter Correction can be secured by arthroplasty where movement is more desirable than stability and strength It is to be noted, however that in the lower extremity a good solid bony arthrodesis is as a rule more useful than is an arthroplasty The latter is apt

to be weak, and may be painful and unstable

In the upper extremity arthroplasties of the shoulders are rarely indicated because arthrodesis with the arm abducted to from 50 to 70° gives a more useful and stable shoulder On the other hand, the elbow is the joint *par excellence* for arthroplasty and gives the most satisfactory result, although it, too is apt to be weak and may be moderately painful after an excelleot operation With the wrist, an arthrodesis with the wrist slightly hyperextended gives a more useful wrist than does an arthroplasty, aod it is stronger Arthroplasties are occasionally indicated for the fingers and for the metacarpophalangeal joints as stiff fingers not only may not be useful but may be an actual handicap to the patient Occasionally, with destructioo of a portion or all of the epiphysis, osteotomies are indicated for correction of alignment Shortening of ooe bone or lengthening of the other extremity may be indicated in an effort to obtain the maximum function of both lower extremities

Treatment of Rheumatoid Arthritis, Including Rhizomelic Spondylosis and Intermittent Hydrops These are diseases for which as yet we have no specific cure, unless it is eventually shown that gold salts may serve this purpose The disease begins insidiously and tends to progress by remissions, and over a period of months or years causes the development of deformities, the stiffening of joints and a variable degree of invalidism of the patient Because it affects not one or two joints, but a large number of joints, surgery is not often iodicated, except in the late stages after the disease has ceased to progress Then surgery attempts to rehabilitate the patient

In the treatment of any chronic arthritis we endeavor to build up the general health of the patient and to establish a sense of well being by the judicious use of a low fat diet, liberal vitamins (especially B and C) and thyroid and theelin where iodicated

During the active stage of the disease every effort should be made to prevent deformity This can be done by the use of splints, by the use of plaster shells to prevent contractures of the extremities, and by the use of traction However, it is to be noted that where the disease tends to progress over a period of months or years, the patient and physician are apt to cease their efforts and a large number of these patients tend to develop flexion deformities of the knees and hips, equinus deformities of the feet, flexion deformities of the elbows, ulnar deviation of the wrist, and the shoulders tend to become stiff at the side

Theoretically, all of the above mentiooed deformities are preventable Practically, it is frequently not possible to continue the preventive treatment over a sufficiently long period Consequently the deformities are not uncommoo During the active stage of the disease the patieot should be encouraged to move all joints daily through their full range of movement and thus not only tend to prevent the muscle atrophy, but also to maintain movement through as great a range as is possible The patient should also be given ample periods of rest After deformities have developed they can be corrected by traction, by plaster of paris encasements, and by splints, as was mentioned above

In applying wedging casts to these patients, particular care should be taken that the extremities are thickly padded over the pressure points, because the skin is usually thin and atrophic and does not stand much pressure In wedging the knee, for instance, thick felt pads are placed over the patella, under the heel, and under the upper thigh In correcting a flexion contracture of the elbow by wedging, a pad is placed over the olecranon, another over the front of the upper arm, and another over the front of the wrist It is io this type of flexion deformity that plastic operations oo the joint capsules, ligaments, and tendons are especially useful after the disease has ceased

to progress These operations are described in Part 2 of this chapter for the various joints

Likewise the operation of *synovectomy* is almost limited to this type of arthritis Not only is this operation indicated in instances where the disease has apparently ceased to progress and has left the joint with a thick *synovia* but *it* is also used in large boggy knees in the active stage of the disease In a patient in whom the arthritis is not active the object of the operation *is to improve* the function of the joint In a patient in whom the arthritis is active the operation of synovectomy not only tends to result in improvement in the function of the joint, but by removing the large mass *of diseased tissues* it eliminates the most important focus of active disease and may result in improvement of the patient s general condition

Arthrodesis is rarely indicated in patients with rheumatoid arthritis because these joints tend to arthrodese by bone Arthroplasty, on the other hand is indicated not infrequently This is especially true in patients with *rhizomelic spondylosis* in whom bilateral joints especially the hips and knees have become ankylosed Osteotomies are used for the correction of deformity Occasionally there is a large amount of thickening around the tendon sheaths this thickening may be removed by operation I believe that spinal fusion should be done in selected early cases of rhizomelic spondylosis This operation tends to prevent deformity and may aid in arresting the disease

Treatment of Degenerative Arthritis, Including Malum Coxae Senilis This is a progressive degenerative disease of the articular cartilage in which the joints appear to be worn out It affects especially the weight bearing joints The patients are usually beyond middle age and are usually overweight They should be corrected as to their body mechanics They should be encouraged by exercise to develop good posture, they should lose excess weight, and the feet and ankles may be supported by shoes with Thomas heels For an adult male the heel is extended forward on the inner border about three fourths of an inch and is elevated on the inner border three sixteenths of an inch at the front and one eighth of an inch at the rear of the heel Some of these patients are given rubber or felt arch supports for the shoes Sometimes the joints are bandaged temporarily by elastic bandages or the patients are given elastic supports such as anklets ankle braces or knee caps for the knees The back is supported by a suitable corset or brace where indicated

These patients are also given exercises in order to strengthen their muscles and are put on a regime of relative rest in order to spare the weight bearing joints We also endeavor to build up their general health and to establish a sense of well being by the judicious use of a low fat diet, liberal vitamins (especially B and C) and thyroid and theelin where indicated We assure them that they do not have the crippling type of arthritis unless the hip is involved, and that they are not headed for a wheel chair During recent years certain operations have been developed for the improvement of function in the joints of degenerative arthritis which are markedly crippled as a result of the disease One of the simplest of these is removal of loose bodies when they are present in the joint The loose body not only tends to interfere with function but it appears to cause progression of the degenerative arthritis

Another operation which has been developed more recently is removal of the patella in patients in whom the patella is markedly enlarged and the cartilage has degenerated A third is revision of the knee joint, which is an extensive operation described in Part 2 of this chapter

For the hip the Smith Petersen acetabuloplasty is useful in those joints where the cartilage is good and where the head

of the femur is unusually large, as in an old Legg Perthes' disease It has given disappointing results in joints where the cartilage has degenerated so that the joint space has been lost For this type of malum coxae senilis an arthrodesis offers the best result. However, the latter cannot be used very often because the disease tends to be bilateral and because the operation and the prolonged convalescence are a formidable undertaking in an elderly patient For this reason the oblique osteotomy of McMurray is being used more frequently Also, the cup arthroplasty of Smith Petersen is used It has been successfully used in many cases The technic and after care must be carefully observed For the feet where large, painful spurs are present, they should be removed The Keller operation has seemed to us to be the most useful for hallux rigidus

Occasionally, in the large boggy joints with degenerative changes in the cartilage and where the synovial membrane is thickened—the so-called villous arthritis—a synovectomy is indicated For localized pain around the knee or elsewhere, injection of novocaine into the painful area may afford permanent relief The painful wrist of stenosing tenosynovitis over the styloid process of the radius may be considered in this section, as it is frequently associated with degenerative arthritis It can be relieved by prolonged immobilization or merely by rest in mild cases and in severe cases by opening the tendon sheath and leaving it open when the wound is sutured See also Chapter 10

Treatment of Traumatic Arthritis In an acute traumatic arthritis—that is in a joint which has been acutely injured by trauma and in which there is apparently no injury to the bone—the early treatment consists of rest by immobilization, and this should be continued until the acute symptoms have subsided Excess blood or fluid should be aspirated When the acute symptoms have subsided and partial function is resumed, the joint should be protected from further injury by adhesive strapping or elastic bandages or by a brace, or in some instances by a plaster-of paris encasement until sufficient time has elapsed to permit the damaged tissues to heal

If there is permanent damage to the joint, it will tend not only to interfere with function but will also cause the arthritis to progress A torn semilunar cartilage of the knee or a relaxed lateral or crucial ligament of the knee should be taken care of by an appropriate operation Where there is a deformity due to a fracture, or a disturbance in epiphyseal growth which causes malalignment of the extremity, forcing the joint to work at a mechanical disadvantage, this deformity should be corrected by an osteotomy In certain instances the articular cartilage is contused by the trauma and degenerates and necroses This area of necrotic cartilage, if it can be identified, should be removed Where the joint is completely disorganized and where satisfactory function is no longer possible, a useful extremity may be obtained by an arthrodesis or by an arthroplasty If strength and stability are prime requisites, the arthrodesis is preferable If movement is desired at the sacrifice of strength and stability, the arthroplasty is indicated

Treatment of Foreign body Arthritis The presence of a foreign body in or near a joint tends to cause a progressive degenerative arthritis of this joint This is true whether or not the foreign body is infected For this reason it is of first importance that such foreign bodies be removed when they are discovered If they are removed early a normal joint may be expected. If they have been in or near the joint over a period of months or years a degenerative arthritis may be present and this should be treated along the lines laid down in the section on degenerative arthritis

Treatment of Hemophilic Arthritis. It is important that this disease be recognized before operation is undertaken, otherwise the patient may be subjected to fatal hemor

rhage In the acute stage these joints may resemble a pyogenic arthritis and in the subacute or chronic stage they may resemble an atrophic or tuberculous arthritis Where the joint is filled with blood under marked tension this may not only be exceedingly painful but tend to cause arthritis in the joint This blood may be aspirated through a fine bore needle and then a pressure dressing applied around the joint Aspiration should be followed by complete rest and support until the acute symptoms have subsided Where marked contractural deformities are present they may be treated by a wedging plaster or by traction care being taken not to cause undue pressure at any given point

[The prevention of deformities in these cases as in rheumatoid arthritis is important The same measures are used in both —Ed]

Treatment of Neurotrophic Arthritis These are the typical Charcot joints In the early stages they are best treated by rest and avoidance of the wear and tear of ordinary use Operative intervention is rarely indicated I know of no instance where solid bony ankylosis of the hip has been obtained after an arthrodesing operation on a Charcot hip I do know and have experienced a number of instances where a Charcot knee has been successfully arthrodesed and a useful extremity has been obtained As a rule however it is more satisfactory to fit the limb with an adequate brace which not only protects the joint but prevents motion For the hip a Thomas ring walking splint should be used For the knee an ordinary upright brace with a hinge joint and with a stop at the straight position can be used For the ankle a double upright brace with a T strap or a well fitting leather or celluloid casement within the double upright brace may be indicated In instances where trophic ulcers with chronic infection are present in the balls of the feet the offending metatarsal heads and the diseased tissue should be excised and the wound closed after sprinkling sulfathiazole powder in the wound

Part 2 Procedures

ASPIRATION OF JOINTS

Joints are aspirated to remove fluid for diagnostic purposes to relieve tension in the joint, or to remove excess purulent material They are also sometimes entered for the purpose of injecting material into the joint It is to be noted that when aspiration of a joint is indicated that joint contains an excess amount of fluid Consequently the synovial cavity of such a joint is more easily entered with the aspirating needle than is the normal joint Most of the joints of the extremities can be aspirated with relatively little difficulty provided the surgeon can visualize the anatomy of the joint and the outline of the synovial cavity At the same time it must be remembered that the synovial membrane has a relatively rich nerve supply and it is advisable to infiltrate the area with 1 per cent novocaine prior to the introduction of the aspirating needle

For joint aspiration the following are required

(1) A 20-cc Luer or record syringe (2) a 20 gauge aspirating needle (3) a 2 cc hypodermic springe (4) a hypodermic needle (5) a few cubic centimeters of 1 per cent solution of novocaine (6) a bottle of tincture of iodine or other skin antiseptic (7) an applicator and (8) a pair of sterile forceps for handling the syringes and needles as it is difficult to maintain sterility if the needles are picked up in the fingers and placed on the syringe

A site is selected for the entrance of the needle and this area is painted with skin antiseptic Usually a round spot about one inch in diameter is painted with iodine and the needle is inserted in the center of this spot [If very carefully and meticulously

done as described here, this technic is a perfectly safe one from the standpoint of asepsis However many men prefer to give the skin more careful preparation, to wear gloves, and to drape the part with sterile towels (See aspiration of the knee joint, Chapter 38, and aspiration of the elbow joint Chapter 31) These latter precautions may seem to some to constitute unnecessary complication of a simple procedure, but the results of a joint infection can be so devastating that the extra precautions are held justified It is also felt that a small skin nick should be made after the initial skin wheal of novocaine, so that the needle which enters the joint does not pass through intact skin —Ed] Before inserting the aspirating needle the 2 cc hypodermic syringe is filled with novocaine and the skin in the spot selected is infiltrated with a few drops of novocaine The hypodermic needle is directed toward the joint cavity and pushed slowly inward as novocaine is forced into the tissues As a rule it is possible to reach the synovial surface without undue discomfort the entire layer through which the larger needle is passed being anesthetized The aspirating needle is then plunged directly into the synovial cavity After the needle is in the cavity, the fluid should be withdrawn slowly as it sometimes contains masses of coagulated fibrin and the needle may become stopped up When this occurs a small amount of air or fluid may be forced back into the joint cavity Then, very slowly, the fluid may be withdrawn again It is important that the needle should not penetrate the synovial membrane on the opposite side of the joint

The site of election of aspirating various joints is as follows

Shoulder The shoulder can be aspirated from the front, from the side, or from the back As a rule, however, since there is usually an anterior swelling the needle is inserted at a point about one inch mesial to the tip of the acromion and about one half of an inch below its anterior margin, and is directed backward and slightly downward

Elbow This joint may be aspirated from the side or from behind As a rule, it is most convenient to enter the joint from behind and distal to the external condyle of the humerus The joint is flexed, causing this area to bulge, and the needle is directed directly inward and slightly forward The needle may be inserted just lateral to the olecranon

Wrist The wrist joint is best entered from the dorsal surface, the needle being inserted in the space between the tendons of the extensor longus of the thumb and of the first finger about one half of an inch proximal to the tip of the styloid process of the radius and is directed toward the volar surface It may also be aspirated on the ulnar side, just distal to the head of the ulna, when marked distension appears in this area

Hip The hip joint may be aspirated from the front, from the side, or from behind As a rule it is most convenient to enter the joint from the front The head of the femur lies behind the center of Poupart's ligament —that is, halfway between the anterior superior spine of the ilium and the symphysis pubis—and it is at this point that the femoral artery crosses Poupart s ligament Consequently the aspirating needle is inserted into the skin approximately one inch below the center of Poupart s ligament and one half of an inch lateral to the femoral artery Before inserting the aspirating needle it is advisable to palpate the artery and to place the needle far enough lateral to it so that the femoral nerve, which lies directly lateral to the artery, will be missed by the needle The needle is then inserted directly backward—that is, directly downward with the patient lying on his back In the lateral approach the needle is inserted just below and anterior to the greater trochanter and is directed inward and upward at an angle of about 30° with the thigh and roughly parallel to the axis of the neck of the femur,

and it should be kept close to the anterior surface of the neck of the femur until the joint capsule has been penetrated

Knee The needle may be inserted on either the outer or the inner side of the joint approximately one half of an inch above and one half of an inch lateral to the upper pole of the patella It is directed backward, inward and downward so that the point of the needle tends to enter the space between the patella and the anterior surface of the femur If the joint does not contain considerable fluid, pressure made in the popliteal space and also pressure made in front below the patella tend to force what fluid there is in the joint upward into the quadriceps bursa and thus float the patella and permit the needle to enter the space without difficulty

Ankle The ankle is best aspirated from the anterolateral aspect that is, just between the external malleolus and the lower end of the tibia and the superior surface of the astragalus The needle is inserted one half of an inch above and one half of an inch mesial to the tip of the external malleolus and is directed backward and slightly inward

INCISIONS OF JOINTS FOR DRAINAGE

In performing an arthrotomy for the purpose of draining a septic joint it is important that the procedure consume a minimum of time The incision should be no longer than necessary, it should avoid important structures and the distance from the surface of the skin to the joint cavity should be as short as possible The joint should be drained adequately and in such a manner that gravity will tend to direct the *secretion from the joint outward* In other words, the drainage should be posterior or downhill if practicable It is important in making such incisions that the cut made be vertical to the skin and that the *subcutaneous tissues* not be *lifted* up or separated from the underlying layers and thus permit extravasation of purulent material around the margins of the incision Acceptable methods of draining various joints follow

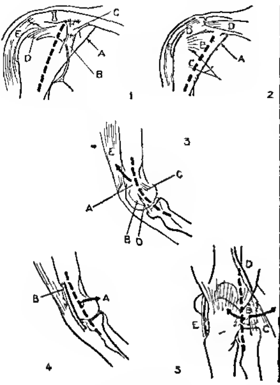
Upper Extremity (Figs 379 and 380)

Shoulder The shoulder may be drained from either in front or behind The anterior incision is somewhat simpler and is usually adequate The posterior incision requires a deeper dissection but has the advantage that if the patient is recumbent there is dependent drainage

Anterior Incision A straight incision about two inches in length is made over the *anterior* aspect of the head of the humerus This incision begins opposite the anterior border of the clavicle near the acromioclavicular joint—that is about two inches mesial to the tip of the acromion—and extends directly downward for a distance of about two inches It is carried through the subcutaneous tissue and fascia to the deltoid muscle The fibers of this muscle are separated by blunt dissection and the distended capsule will be found beneath the muscle This is incised in line with the incision and the purulent material in the joint is evacuated If desired the joint *may* be *irrigated* with normal salt solution or some antiseptic solution

Posterior Incision This incision begins at the spine of the scapula about one and one half inches mesial to the tip of the acromion and extends directly downward for a distance of about two inches in line with the fibers of the deltoid muscle The incision is carried through the deep fascia, and the fibers of the deltoid muscle are separated by blunt or sharp dissection to reveal the short external rotators of the shoulder joint *These are defined* by *blunt* dissection and the incision is deepened between the infraspinatus and teres minor muscles When these muscles are separated the capsule is exposed This is incised and the contents of the joint are evacuated

After treatment After drainage of the



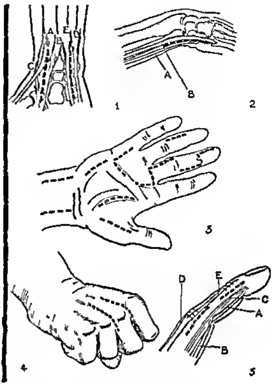


FIG 379 (*Left*) **Drainage incisions—(1) Anterior shoulder** (A) Deltoid margin, (B) coracobrachialis and short head of biceps attaching to (C) coracoid process, (D) supra spinatus, (E) subdeltoid bursa

(2) **Posterior shoulder** (A) Posterior deltoid margin, (B) infraspinatus, (C) interval between infraspinatus and teres minor, (D) supraspinatus, (E) deltoid and subdeltoid bursa

(3) **Lateral elbow** (A) External epicondyle, (B) anconeus (C) extensor carpi radialis, (D) line of separation between (B) and (C), (E) triceps—arrow represents line of retraction of reflected triceps attachment from suprascapular ridge for extension

(4) **Internal elbow** (A) Internal epicondyle, (B) ulnar nerve—arrow denotes line of retraction

(5) **Posterior elbow** (B) Anconeus and triceps, (C) extensor carpi radialis, (D) radial nerve, (E) ulnar nerve—arrow denotes lines of retraction

FIG 380 (*Right*) **Drainage incisions—(1) Dorsal wrist, radial and ulnar** (A) Ex tensor longus pollicis, (B) extensor indicis proprius, (C) extensor carpi radialis, (D) extensor carpi ulnaris, (E) extensor of little finger

(2) **Mesial wrist** (A) Flexor carpi ulnaris, (B) extensor carpi ulnaris

(3) **Finger and palmar spaces**

(4) **Metacarpophalangeal joints** Note flexion of fingers They must be kept this way during drainage period

(5) **Interphalangeal drainage** (A) Extensor profundis, (B) extensor sublimis, (C) digital vessels and nerve, (D) and (E) extensor tendon attachments

shoulder it is advisable that the arm be supported in approximately 90° of abduction until the acute symptoms have subsided. It is important to note that neither of the above incisions should be carried too far downward, otherwise the circumflex nerve which supplies the motor fibers to the deltoid muscle may be injured.

Elbow. The elbow is preferably drained from the lateral side. However, it may also be adequately drained from the mesial side and occasionally through and through drainage is advisable. The mesial incision has the advantage that, since the patient is usually recumbent, it supplies dependent drainage. The lateral incision, however, offers a wider opening into the joint.

Lateral Incision. The incision begins about one inch above, and extends downward and backward to a point about one inch below, the external condyle. It is carried through the deep fascia and exposes the anconeus and the extensor carpi radialis muscles. The extensor carpi radialis is separated from the anconeus and the incision is carried directly into the joint, opening into the space between the external condyle and the head of the radius. If desirable, the incision may be extended upward along the ridge above the external condyle to drain the posterior compartment of the joint by elevating the attachments of the triceps from the lateral ridge.

Internal Incision. This begins about one inch above the internal condyle and extends directly downward to a point about one inch below the condyle. It is carried directly down onto the condylar ridge and extended just anterior to this ridge, the fibers of the brachialis anticus being lifted from the ridge if necessary. Thus the ulnar nerve which lies behind the condyle is not exposed in the incision. The joint capsule is opened between the internal condyle and the coronoid process of the olecranon.

Posterior Drainage. Somewhat simpler, but less efficient, drainage may be provided by making a longitudinal incision just lateral to the olecranon process. This is deepened into the joint, separating the fibers of the triceps from the olecranon. The mesial posterior incision is not advised because of danger of injury to the ulnar nerve.

After drainage the elbow should be maintained at approximately 90° flexion by a splint or by suspension or a circular plaster. A heavy hot wet dressing may be used to immobilize the joint and also to reduce or prevent cellulitis.

Wrist. Dorsal Incision. The wrist is best drained by a dorsal incision. This is placed between the tendons of the extensor longus pollicis and the extensor indicis proprius muscles and begins about an inch above the wrist joint and extends directly downward to about an inch below the wrist joint, passing through the dorsal carpal ligament. A similar dorsal incision may be made on the ulnar side between the extensor carpi ulnaris and the extensor tendon of the little finger.

Mesial Incision. The mesial incision on the ulnar side lies between the flexor and extensor carpi ulnaris muscles. It begins about one inch above the head of the ulna and extends directly downward across the joint, cutting through the ulnar collateral ligaments just distal to the styloid process. In this incision it is important not to disturb the attachments of the triangular interarticular fibrocartilage.

After incision for drainage the wrist should be fixed in dorsiflexion by a splint or circular plaster.

If the infection involves the metacarpal or carpometacarpal joints, either of the above mentioned dorsal incisions may be extended directly downward as far as necessary onto the dorsum of the hand. If the infection is quite far advanced and there is marked destruction of the bones and it is advisable to excise one or both rows of carpal bones, the incision between the extensors of the thumb and the index finger is the only incision necessary, and this can

be enlarged toward the ulnar side subperiosteally and the diseased bones can be exposed and removed

Carpometacarpal Joints These joints are best drained by dorsolateral incisions, one on either side of the involved joints The incision is made between the metacarpal heads with the fingers flexed, and is carried down to the joint, the capsule being incised longitudinally on each side In the thumb, the second, and the fifth fingers, the incisions can be made as in draining the interphalangeal joints—that is, the dorsolateral aspect on either side

Interphalangeal Joints These joints are best drained through posterolateral incisions, one on either side, about halfway between the middle of the lateral surface of the joint and the dorsum of the finger, thus avoiding the digital artery and nerve Sometimes this damages the dorsal sensory nerves This however, is not serious The incisions are carried directly down to the joint, and the capsule is incised on both sides, so that neither tendon is exposed to the infection

Lower Extremity (Figs 381 and 382)

Hip The hip may be drained from the front, the back, or from the lateral or mesial side As a rule, I prefer the anterior incision because it is simpler, more quickly performed, and opens the joint more widely The posterior incision has the advantage that it supplies dependent drainage However, it has the disadvantage that this drainage must pass between the small rotators of the hip which are taut and lie quite close to the back of the neck of the femur and also that a relatively small portion of the joint capsule is exposed from behind, since the capsule is attached quite close to the head on the posterior portion of the neck This is especially true when the hip is externally rotated Then, the posterior rim of the greater trochanter almost reaches the rim of the acetabulum and makes exposure and drainage difficult

Anterior Incision This begins just below the anterior superior spine of the ilium and extends directly downward between the sartorius and the tensor fascia femoris muscles for a distance of from two to four inches, depending upon the size of the patient It is carried through the deep fascia and the two muscles are separated by blunt dissection and the fatty tissue beneath them is incised or wiped out with a sponge down to the capsule of the joint This is incised, usually longitudinally along the anterior border of the neck, to evacuate the pus and then a cross incision is made to assure adequate drainage If the incision is carried unusually far down on the thigh the anterior circumflex vessels may be seen in the lower portion of the incision If these vessels are exposed they should be tied with chromic catgut, because if they are left exposed in the wound, which is apt to be filled with pus, their walls may be eroded and they may give rise to troublesome secondary hemorrhage

Posterior Incision (Ober or Langenbeck) The patient lies on his sound side with the affected hip moderately flexed The incision lies parallel to and directly posterior to the neck of the femur and parallel to the fibers of the gluteus maximus muscle It begins at a point about one third of the way from the posterior superior spine of the ilium to the base of the greater trochanter and lies in this line It is extended downward and outward over the base of the trochanter through the deep fascia The fibers of the gluteus maximus muscle are separated, disclosing a layer of fat This is incised, care being taken not to injure the sciatic nerve which lies in the median angle of the incision It is advisable not to expose this nerve if the exposure can be avoided After the fat is incised and separated by blunt dissection the short rotators of the hip come into view and must be separated to expose the capsule of the femur These muscles are separated by blunt dissection or, if necessary, they may be divided from

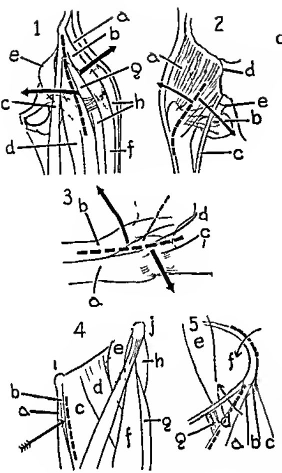


Fig 381

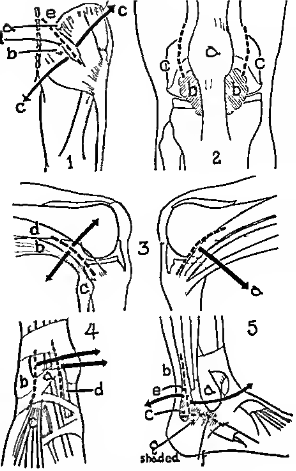


Fig 382

Fig 381 (1) **Anterior incision** blocked line is that of skin incision, arrows indicate retraction (a) Gluteus medius, (b) tensor, (c) sartorius, (d) rectus, (e) psoas iliacus, (f) iliotibial band, (g) exposed femoral neck

(2) **Posterior incision** (a) gluteus medius, (b) obturator and gemelli (c) sciatic nerve (d) posterior superior spine, (e) ischial spine Blocked line is that of skin incision, arrows indicate retraction

(3) **Lateral incision** Skin incision and retraction as above (a) Vastus lateralis, (b) rectus, (c) gluteus medius (d) tensor

(4) **Mesial incision of Ludloff** blocked line indicates skin incision (a) Gracilis, (b) adductor brevis, (c) adductor longus, (d) pectineus, (e) psoas iliacus and iliopectineal bursa, (f) rectus, (g) vastus lateralis, (h) gluteus medius (i) symphysis, (j) anterior superior spine Arrow indicates route between adductor longus and adductor brevis and beneath former and pectineus and psoas iliacus

(5) **Incision for iliopsoas abscess beneath Poupart s ligament or over iliac crest** Anterior incision parallels sartorius border Iliac crest incision detaches internal and external oblique (a) Rectus, (b) tensor, (c) gluteus medius, (d) sartorius, (e) psoas, (f) iliacus, (g) femoral vessels

Fig 382 Drainage incisions—(1) **Incision for sacro iliac joint** (a) Anterior superior iliac spine, (b) posterior inferior iliac spine (c) retraction of gluteus in line of its fibers, (d) exposed portion of capsule of joint Blocked line indicates skin incision

(2) **Internal and external lateral incisions for knee-joint drainage** (a) Patella, (b) fat pad location, (c) anterior margin of femoral condyle Blocked line shows skin incision

(3) **Lateral and mesial posterior incisions of Henderson** (a) Inner hamstrings, (b) biceps tendon, (c) fibular head, (d) iliotibial band Blocked lines indicate incisions

(4) **Anterolateral and anteromesial ankle drainage** Blocked lines show incisions in skin (a) Lower border of tibia, (b) external malleolus, (c) extensor tendons, (d) tibialis anticus

(5) **Posterolateral ankle drainage (David)** (a) External malleolus, (b) tendo achillis, (c) superior surface os calcis (e) flexor longus hallucis (f) downward extension through fat pad if subastragalar *joint drainage is desired,* (g) *fat pad* Arrows indicate retraction

their insertion in the trochanter and permitted to retract As a rule, the muscles are not separately identified, but it is probable that the separation is between the obturator *internus* tendon and the *gemellus above* or below it The capsule is incised longitudinally If this is not deemed sufficient, the external rotator muscles may be divided and the capsule may also be incised transversely

LATERAL AND MESIAL INCISION In certain instances abscesses point either laterally in *front of the greater trochanter or* mesially on the inner side of the thigh In such instances it is advisable to open these abscesses if the patient is quite sick. The lateral incision lies just in front of the trochanter and extends downward in line with the shaft of the femur It is deepened through the deep fascia and carried in toward the hip along the anterior border of the neck of the femur and the capsule of the joint is incised In instances where the bone is diseased it is advisable to make a lateral incision downward from the tip of the trochanter and to open the cortex of the bone in the cancellous region opposite the base of the neck This incision may be extended inward along the anterior border of the neck and the joint may be drained through this incision

The mesial incision of Ludloff begins near the tuberosity of the ischium and extends downward for about three inches between the adductor longus and the adductor brevis muscles These muscles are separated by blunt dissection and the abscess cavity is opened and drained

In children in whom the hip-joint infection has been present for some days, and in which it is found on opening the joint cavity that the head of the femur is separated the head should be removed This is most easily removed through the anterior incision

With extensive disease of the neck both anterior and posterior incisions are sometimes advisable in order that through and through drainage may be established However, it is important that as little surgery as possible be done on a very ill patient, and in patients who are very toxic the anterior incision is to be preferred, as it affords wider drainage and can be done more quickly and with less disturbance to the patient

After the drainage the hip should be immobilized, either by skin or skeletal traction or in a plaster of paris spica, in a position of moderate abduction and very slight *flexion and in the neutral position* as regards rotation

Pelvic Abscess Occasionally a pelvic abscess develops in patients with acute pyogenic arthritis of the hip as a result of suppurative lymphadenitis in the glands along the course of the external iliac artery The abscess lies retroperitoneally and tends to gravitate along the course of the iliopsoas muscle and Poupart s ligament, pointing subcutaneously over the pectineus muscle, between the adductor longus and the adductor brevis

Freiberg advocates Ludloff s incision passing a blunt hemostat between the adductor longus and the adductor brevis muscles where the abscess points on the inner side of the thigh When it points subcutaneously below Poupart s ligament it may be drained by a small vertical incision, care being taken to avoid large vessels and to keep the incision well lateral to the femoral artery and vein

The usual iliopsoas abscess is most easily and effectively drained by an anterolateral incision which lies just above the anterior portion of the crest of the ilium and the adjacent portion of Poupart s ligament This incision is carried down to the crest of the ilium and the lateral abdominal muscles are cut from the bone for a short distance and the pelvic cavity is entered care being taken to keep the dissection close to the inner surface of the ilium and not to open the peritoneal cavity As the peritoneum is pushed forward the abscess is usually en

countered and is opened by blunt dissection

Sacro iliac Joint Occasionally the sacro iliac joint is the primary seat of a pyogenic arthritis Usually, however, the disease begins in the ilium and extends to the joint Where the joint is believed to be the primary site of the disease, or where the abscess points posteriorly at the lower end of the joint it can be adequately drained by a straight incision which begins near the midline and courses downward and outward in line with the fibers of the gluteus maximus muscle passing just below the posterior superior spine of the ilium This is carried directly downward to the bone and the fibers of the gluteus maximus muscle below the posterior superior spine are separated to expose the lower end of the joint The capsule of the joint is exposed between the posterior superior and the posterior inferior spines of the ilium, and can be incised and drained here Usually it is advisable to remove a variable amount of the adjacent bone which may be diseased in order that an adequate opening into the joint may be obtained

Knee The knee is most easily and effectively drained by two parallel incisions one on either side of the patella placed about halfway between the lateral border of the patella and the anterior border of the condyle of the femur It is important that these incisions be placed well out from the patella in order that in their lower portion it will not be necessary that the dissection pass through the fat pad before the synovial cavity is entered Also by placing them well out from the patella more adequate drainage is obtained Depending upon the size of the patient the incisions vary from two to three or more inches in length The incisions are carried directly through the aponeurosis and into the articular cavity Not infrequently, on one or both sides the middle geniculate artery will be cut this should be ligated as well as any other important vessels encountered

As a rule, the two anterior incisions are adequate Occasionally infection persists in the posterior compartment of the knee When this occurs the posterior compartment should be drained by two short incisions, the lateral and mesial incisions of Henderson The anterior incisions described above are made with the knee joint extended The lateral or posterior incisions are made with the knee joint flexed The one on the inner side passes anterior to the internal hamstring muscle The section is carried directly down to the bone and into the posterior compartment of the knee The one on the outer side lies anterior to the biceps tendon and head of the fibula It is continued through the iliotibial band into the joint cavity

After the knee has been opened for drainage it should be immobilized in a position of full extension either by traction in a splint or else in a plaster of paris encasement

Ankle The ankle may be drained anteriorly through a lateral or mesial incision or posteriorly through a lateral incision The simplest incision is the anterolateral incision which begins about an inch above the lower border of the tibia and about one half of an inch mesial to the external malleolus *It is carried directly downward* and the dissection is continued through the fascia and fat tissue lateral to the extensor tendons and into the synovial cavity of the joint The anteromesial incision begins about an inch above the ankle joint and is extended downward along the mesial border of the anterior tibial tendon and into the ankle joint care being taken not to open the sheath of the tendon of tibialis anticus

The posterolateral incision of David is said to be more effective than either of the above With the foot in a position of dorsiflexion the incision begins about two inches above the tip of the external malleolus and just lateral to the tendo achillis, and is carried downward to a point opposite to the

superior surface of the os calcis at which point it is curved forward parallel with the superior surface of the os calcis If the external saphenous vein is exposed in this incision it is ligated and the exposed portion is excised The flexor longus hallucis tendon is retracted mesially and the fat above the subastragaloid joint is pressed downward and the ankle joint capsule is incised under direct vision If desired, this incision may also be used for drainage of the subastragaloid joint by extending the incision downward through the fat pad and opening this joint

Subastragaloid Joint Occasionally severe infection in the os calcis or in the astragalus involves the subastragaloid joint This joint is most adequately drained by the heel splitting operation of Gaenslen (p 478)

In other infections of the tarsal bones the incision should lie above the most prominent point of the abscess and the involved joint Usually, however, unless these tarsal infections are opened very early, the infection tends to spread widely and involve all of the tarsal joints After the operation and drainage the foot should be immobilized in a position of slight equinus in a plaster of paris encasement which extends above the knee

Postoperative Treatment of Septic Arthritis After the joint has been opened, the edges of the operative wound should be covered with vaseline gauze in order to protect them and to prevent the dressing from sticking to them In addition to this, a drain, either of vaseline gauze or of soft rubber tissue, is inserted down to the synovial membrane Its position should be maintained As a rule, it is advisable to fasten this drain I prefer vaseline gauze which is well impregnated with vaseline and has no free threads which may come off, and I fasten it to the synovial membrane by a single suture of plain catgut This maintains the drain in place over a period of several days At the end of this time the catgut will have dissolved and the drain can be removed without difficulty

As was stated above, it is important, especially in ill patients, to conserve the patient s blood and to ligate vessels as soon as, or before, they are cut Also, vessels which are exposed in the wall of the incision should be ligated and excised between ligatures rather than permitted to remain, because there is always the danger that the walls may be eroded and cause secondary hemorrhage

After the operation is completed and the drains are inserted, the edges of the wounds are lined with vaseline gauze which overlaps the skin A wet or dry dressing is then applied, depending upon whether or not the limb is to be immobilized in a splint or in plaster of paris As a rule, I prefer plaster of paris because it provides more complete immobilization, the plaster being applied as a spica for the hip or shoulder, and a cylinder encasement for the knee or ankle or foot It is applied over adequate padding It is *not* a skin tight plaster The joint is irrigated with hot normal salt solution before the drains are inserted and the dressings are applied If a wet dressing is used, this should be a massive wet dressing and should be kept warm If plaster is used the dressing need not be especially large and should be dry

The shoulder is immobilized in moderate abduction (about 135°), the elbow in slight flexion (about 130°), and the wrist in dorsiflexion (about 30°) In immobilizing the wrist, the immobilization should include the fingers and thumb, the entire hand should be immobilized, and the elbow as well The hip should be immobilized in moderate abduction and extension, the knee in full extension, and the foot in 90° dorsiflexion or slight plantar flexion After extensive operations on the foot, the knee should also be immobilized The plaster is left on until it should be changed because of excessive

drainage, which may cause a softening of the cast and a foul odor, or because it is no longer necessary since the disease has subsided sufficiently to warrant removal of the drain After the wound is dressed the edges of the wound may be kept separated with vaseline gauze which extends down to or nearly to the synovial membrane This is continued until the infection in the joint has been eliminated and the opening in the synovial membrane has healed Then the wound is allowed to heal by granulation keeping it covered by vaseline gauze

As a rule I sprinkle a considerable amount of sulfanilamide crystals in the joint cavity and in the wound before inserting the vaseline gauze drain This does not eliminate the infection but it tends to decrease the severity of infection and I believe that it is beneficial in the healing of the wound It may make the difference between a useful joint and an ankylosed joint Other things being equal the sooner the joint is opened and drained after the infection begins the less is the danger of ankylosis Ankylosis is less apt to occur if the bone is not involved

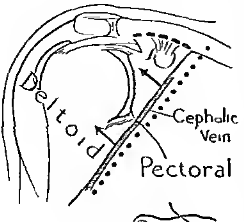
Pyogenic Arthritis of Hip In pyogenic arthritis of the hip in children it is important that abduction be maintained Otherwise, dislocation of the femur or of the neck of the femur with separation of the head may occur If the former has occurred before intervention then—if the dislocation is not reduced at the time of the drainage and if the limb is immobilized in plaster of paris—as soon as the general condition of the patient permits the limb should be put up in traction and an effort made to pull the head down into its normal position If the head has been separated from the neck removal of the head must be considered at this time

Treatment by Movement Treatment of pyogenic arthritis by active exercises was begun or at least popularized during the First World War by Wilms According to Wilms technic the joint is opened widely and the wounds are left open just as described above, the difference being that instead of immobilizing the limb in plaster of paris, the joint is placed in a splint using a Thomas splint for the leg and usually balanced traction for the elbow and shoulder A dry dressing only is placed on the wound The limb is suspended in a position opposite to that of the deformity which the joint tends to assume if ankylosis should occur—that is the shoulder is suspended in moderate abduction and extension the elbow is suspended in almost complete extension the hip is suspended in extension and abduction the knee is suspended in complete extension and the ankle is suspended in dorsiflexion Then every two hours day and night the patient is visited by a nurse who insists that the patient move the joint voluntarily This active movement is begun as soon as the patient is sufficiently awakened from the anesthetic to cooperate and is continued until drainage of the joint has nearly ceased and the active inflammation has quieted down

The theory behind the Wilms treatment is that active movement forces the purulent material out of the joint cavity Undoubtedly if properly carried out it will result in a movable joint in certain patients with pyogenic arthritis in whom fibrous or bony ankylosis would have occurred had the joint been immobilized On the other hand, it requires that the patient be in a hospital where he can be closely supervised by trained assistants In the beginning the movement is accompanied by considerable pain but after two or three days the patient is able to move the joint through a considerable range without sufficient pain to interfere with the treatment However, if the patient stops moving the joint over a period of 12 hours or more, it will be found that on resumption of movement more severe pain is encountered Movement is progressively more difficult as time passes without active exercise

ARTHROTOMY FOR REMOVAL OF LOOSE BODIES IN JOINTS

The joints most subject to the development of loose bodies are in the order mentioned—the knee elbow shoulder, hip, and occasionally the ankle The loose bodies may be due to osteochondritis dissecans to fractures of the articular surface, or to chondromatosis of the synovial membrane



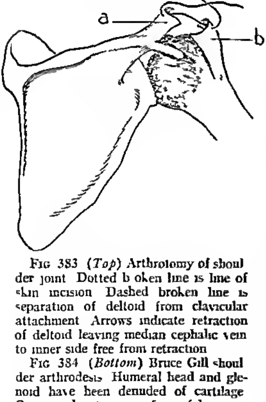


Fig 383 (*Top*) Arthrotomy of shoulder joint Dotted broken line is line of skin incision Dashed broken line is separation of deltoid from clavicular attachment Arrows indicate retraction of deltoid leaving median cephalic vein to inner side free from retraction

Fig 384 (*Bottom*) Bruce Gill shoulder arthrodesis Humeral head and glenoid have been denuded of cartilage Outer and anterior surface of humerus has been elevated as a thin shell with attached capsule (b) Head has been split and denuded acromion placed in split Periosteal and fascial flap stripped from superior surface of acromion (a) is ready for suture to (b) (See p 437)

Shoulder Arthrotomy of the shoulder is best performed through the anterior incision as described above (p 425) In a case with very numerous loose bodies where wide exposure of the joint is desired, it is advisable to place the incision mesial to the one described above beginning at approximately the middle of the clavicle and extending downward and outward along the *anterior border of the deltoid muscle* This incision exposes the cephalic vein, which is left to the inner side, the deltoid being retracted outward In order to obtain good exposure of the shoulder it is advisable to cut the anterior fibers of the deltoid from the clavicle for a distance of about one inch (*Fig 383*) This will permit of wide exposure of the shoulder joint and also of the sheath of the biceps tendon When large numbers of loose bodies are present in the shoulder, some of them are apt to be in the sheath of the biceps tendon while others collect in a pouch in the axilla below the margin of the glenoid

Hip In the hip the anterior incision is usually adequate unless there are large numbers of loose bodies In that case the incision may be enlarged by continuing it outward and backward along the crest of the ilium in the manner of the anterolateral approach to the hip of Smith Petersen stripping the gluteus medius and the tensor fascia femoris from their origins to make the exposure as wide as necessary [See Fig 395, p 459]

Elbow In the elbow, the incision described above for drainage along the lateral border of the humerus and the external condyle and downward and backward along the anterior border of the anconeus is usually adequate By stripping the fibers of both the triceps and the brachialis anticus from the humerus the posterior and anterior portions of the joint can be exposed and

all loose bodies usually can be removed It is to be noted that this incision, used in this manner, removes the external lateral ligament of the elbow from its attachments and this should be re applied carefully to the bone as the incision is closed, and the arm should be immobilized in plaster of paris until sufficient time has elapsed to permit healing of the ligament This is usually about three weeks

KNEE In the knee the mesial parapatellar incision is found most convenient if several *loose bodies are present or if they lie between* the condyles of the femur [See Fig 382 p 429] Occasionally where one large loose body is palpable in the quadriceps bursa, this can be removed through a small incision about an inch and a half long if it can be located at the time of the operation and if the incision is made directly over it The loose body may slip away before it is exposed However since it is large it is usually possible without a great deal of difficulty to manipulate it back into the quadriceps pouch near the incision and to grasp it with forceps and extract it The joint is then closed in layers without drainage, as mentioned above

The mesial parapatellar incision of the knee begins slightly to the mesial side of the midline about two or three inches above the patella extends downward and inward along the mesial border of the patella about half an inch mesial to this bone and extends on downward along the mesial side of the patellar ligament to the tubercle of the tibia This incision is carried down through the aponeurosis and into the joint passing through the fat pad in its lower portion Then by reflecting the patella outward to the lateral side of the femur, the entire anterior portion of the joint can be inspected Not only can loose bodies be removed, but, if necessary both semilunar cartilages may be removed through this incision, although removal of the external semilunar cartilage may present considerable difficulty and a short *lateral incision* may be necessary for its complete removal

ANKLE Loose bodies in the ankle joint usually arise from the superior surface of the astragalus I have recently removed one from the posterior lateral portion of this bone This was reached through an incision parallel with the tendo achillis which was carried down to the space between the posterior border of the tibia and the fibula Then when the foot was dorsiflexed, it was possible to identify the loose body and excise it from its bed although the cartilage *was intact over it If the loose* body *is in* the anterior portion of the joint, it can be removed by an appropriate anterior incision as described above for drainage of the ankle

In all of the above incisions the joints are closed in layers preferably with silk with fine interrupted silk sutures for the synovial membrane medium interrupted silk sutures for the joint capsule, fine silk sutures for the subcutaneous tissues and medium silk sutures for the skin Routinely, I sprinkle sulfanilamide crystals in the wound before the joint is closed

OPERATIONS ON SHOULDER

Injection of Novocaine Into Subdeltoid Bursa The point of maximum tenderness on the front of the shoulder over the tuberosity of the humerus is selected This is painted with tincture of iodine or some other skin antiseptic With a hypodermic syringe and needle 1 per cent novocaine is injected into the skin to make a small wheal Then the hypodermic needle is directed directly backward and the subcutaneous tissues and muscles overlying the bursa *are infiltrated with novocaine* A 5 cc syringe is then filled with 1 per cent novocaine and a Wassermann needle is inserted into the wheal and directed directly backward toward the bursa As the bursa is punctured the bone is reached About 2 cc of novocaine are injected at this point Then the needle is partly withdrawn and directed laterally and 2 cc more of novocaine are

injected The same procedure is carried out by pointing the needle in various directions forming a circle of approximately one inch around the point of maximum tenderness

If the x ray has shown the presence of calcified material in the bursa an attempt should be made to direct the needle at this material, and usually the material can be withdrawn in the syringe as a powder like white substance which quickly settles at the bottom of the syringe when mixed with the novocaine solution By this means the wall and floor of the bursa are punctured in several places As a rule, not over 10 cc of 1 per cent novocaine is used In an acute bursitis this procedure frequently gives relief In a chronic bursitis it is very apt to be of little avail, but may be tried before resorting to irrigation or to operative procedures Rather frequently, in my experience, it is apt to be followed by a period of from two to three days during which the injected area is exceedingly painful and tender and the patient s symptoms are markedly aggravated [See also Chapter 11]

Irrigation of Subdeltoid Bursa [See Chapter 11 for technic]

Not infrequently in chronic bursitis it may not be possible to obtain a flow of fluid through the bursa Apparently, in such cases, the bursal cavity is obliterated or the walls are so close together that it is not possible to balloon the bursa so as to get a second needle into it from behind In such instances I have injected a considerable amount of salt solution or of ½ per cent novocaine, usually from 40 to 60 cu cm, into the tissues, endeavoring to balloon out the bursa, and have left this fluid in the tissues In such instances after the novocaine wears off the patient is apt to have a painful shoulder for at least 48 hours This requires codeine and sometimes morphine to obtain relief

Operation for Excision of Wall of Bursa The incision begins at the anterior border of the acromion about one inch mesial to its tip and extends directly downward parallel with the fibers of the deltoid muscle for a distance of about two inches The incision is carried down through the fascia, and the fibers of the deltoid are split to expose the wall of the bursa Before opening the bursa the muscle fibers are pushed back on either side to expose a good part of the anterior wall The amount of exposure can be increased by rotating the humerus from side to side, that is, rotating it inward and outward Then, a wide door or opening is made in the bursa by excising most of the anterior wall of the bursa

Having opened the bursa, calcified material is evacuated, if present Roughenings on the floor of the bursa are excised Any adhesions which cross the wall of the bursa or interfere with joint motion are removed At the end of the operation the humerus is adducted and rotated The interior of the bursa is then sprinkled with sulfanilamide and the wound is closed in layers, using two or three sutures of fine silk to coapt the fibers of the subdeltoid muscles, fine silk for the subcutaneous tissues, and medium silk for the skin The patient is dressed with the arm at the side, or placed in bed with the arm abducted and externally rotated and the wrist fastened by a sling to the head of the bed The latter is preferable in chronic cases in which there has been a considerable amount of adhesion and limitation of motion over a long period of time [See also Chapter 11]

This operation may be carried out under local anesthesia When local anesthesia is used, it is preferable to operate with the patient sitting up in a dental chair according to the technic of L C Abbott This permits the head of the humerus to drop away from the acromion, and also permits free internal rotation, abduction, adduction, and external rotation of the humerus The objection to operating upon these cases under local anesthesia is that even when wide infiltration around the bursa is carried out considerable difficulty is encountered in manipulating the shoulder and increasing

the range of motion because apparently the adhesions posterior to the upper end of the humerus interfere with this motion and cause pain when it is attempted

In instances in which a tear of the supraspinatus tendons is found at the time of the operation, it may be advisable to attempt to repair this If such an attempt is made, the incision is extended upward and backward around the acromion, and the deltoid muscle fibers are detached from their origin, thus affording free access to the torn aponeurosis In suturing the aponeurosis I have removed a part of the tuberosity of the humerus, thus making it smaller than normal, and have then bored holes in the caucellous bone and drawn the aponeurosis forward with silk sutures passed through the hole in the humerus If this tendon is frayed and retracted it is probably wiser to excise the anterior portion and smooth off the floor of the bursa rather than attempt its repair by means of a fascial transplant which will create an irritating mass in the floor of the bursa This extensive repair of the frayed tendon with fascia is an interesting surgical procedure, but I believe that it will usually result in pain and stiffness of the shoulder [A new conception of the pathology and repair of these tears of the musculotendinous cuff of the shoulder has been put forward by Dr Harrison L McLaughlin See Chapter 29 for further discussion of this lesion, with illustrations — Ed]

Axillary Incision for Removal of Loose Bodies in Shoulder In one instance in a young woman where a visible scar was not desirable, I opened the shoulder joint through an axillary incision With the patient on the back and the arm fully abducted the incision is made in the posterior axillary line anterior to the latissimus dorsi muscle This is carried down to the shoulder joint and the capsule is incised A fairly complete exploration of the shoulder is possible

Arthroplasty of Shoulder I have never performed an arthroplasty of the shoulder and do not think that I ever shall perform one Consequently, I do not think it in order to describe the operation here, as an arthrodesis gives a much more satisfactory result

Arthrodesis of Shoulder The relatively small size of the glenoid tends to make an arthrodesis of the shoulder a difficult procedure. I prefer an operation somewhat similar to that described by Bruce Gill (Fig 384, p 434)

Technic With the patient lying on the side, a sandbag under the shoulder, and the arm so draped that it can be moved freely, a vertical incision is made on the lateral aspect of the shoulder This incision begins over the top of the acromion and extends outward over its tip, and then downward over the outer surface of the upper end of the humerus It is carried down to the bone over acromion and through the proximal two inches of the deltoid muscle The skin is retracted anteriorly and posteriorly to expose the attachments of the deltoid to the acromion The muscle is divided a short distance from the bone entirely around the acromion process to give free access to the head of the humerus It is then retracted backward and forward to expose the upper end of the humerus The tissue between the top of the humerus and the acromion is excised by sharp dissection Likewise, the capsule of the shoulder joint in this region is excised Then with a large curved gouge the cartilage is removed from the glenoid fossa and from the head of the humerus By rotating the head of the humerus outward and adducting the arm, its cartilage can be removed without difficulty The periosteum is removed from the deep surface of the acromion and from the base of the spine of the scapula, and thin slivers of bone are cut and lifted up from this region Thus, the entire inferior surface of the acromion, the glenoid, and the upper end of the humerus are denuded of soft tissue and the cortical bone

is roughened Likewise, the soft tissue is detached from the tuberosity of the humerus This includes the supraspinatus and possibly the infraspinatus and teres minor muscle insertions Then a wide flap of bone is raised from the tuberosity of the humerus and left attached at its lower end The acromion process is split horizontally with a broad, thin chisel The lower flap of the latter is forced down toward the head of the humerus The arm is abducted and brought forward and the flap of bone from the acromion is fitted into the cut in the tuberosity of the humerus, and the flap of tuberosity is forced between the two flaps of acromion If desired, a loop of stainless-steel wire is passed through the base of the acromion and the proximal end of the humerus to stabilize the shoulder until the arthrodesis is firm

With the arm maintained in abduction of about 80° and anterior flexion of about 30° the wound is closed A considerable number of vessels may have to be clamped during this procedure The larger ones are tied with fine silk

The wound is then closed in layers, the deltoid muscle being sutured back to its origin from the acromion and the subcutaneous tissues closed with fine silk Care should be taken during the closure of the wound that the arm be maintained in abduction and slight forward flexion

After the wound is closed a plaster of paris spica is applied This gets a firm grip on the pelvis below, and extends down the upper extremity to the wrist, maintaining the arm in a position of abduction and forward flexion with the elbow moderately flexed

In children the shoulder should be placed at approximately 90° and in adults at a little less than 90° (about 80°) abduction It should be flexed forward and internally rotated so that when the elbow is flexed the tips of the fingers will approach the mouth The plaster must be worn until union is firm If it should become loose, it is changed a few weeks after the operation and a more snugly fitting plaster of paris applied If difficulty is encountered in making the cast fit snugly and in maintaining the shoulder in the correct position, the elbow may be supported by a wooden strut which passes upward from the region of the crest of the ilium, incorporated in the plaster It is advisable, before applying the plaster, to bind the shoulder snugly with a spica bandage, preferably of elastic material or flannel As a rule, union should be quite firm within three months after the operation During this period the plaster may be removed and the shoulder x rayed and tested for stability It is expected that some abduction will be lost, the final position being from 50 to 60° of abduction and a position of forward flexion and internal rotation If consolidation is obtained in this position a very useful upper extremity may be assured [See also Chapter 14]

Osteotomy at Upper End of Humerus This operation is occasionally indicated where there is ankylosis of the shoulder in a poor functional position—that is, either with the arm at the side or with the arm in marked internal rotation The operation can be done through the shoulder joint However, if it is undesirable to break up the ankylosis, the operation can be done in the proximal portion of the shaft, just below the groove of the biceps tendon

TECHNIC The incision starts just lateral to the middle third of the clavicle and is carried downward and outward along the mesial border of the deltoid muscle to a point close to the insertion of the deltoid It is carried through the deep fascia leaving the cephalic vein to the mesial side, care being taken not to injure the walls of this vein The deltoid and pectoralis muscles are separated, sacrificing a few of the anterior fibers of the deltoid if necessary In the upper part of the incision the skin and fascia are retracted outward and about an inch of the origin of the deltoid is cut from the clavicle, permitting this muscle to be

retracted outward to expose the region of the shoulder

If it is desired to perform the osteotomy through the site of the ankylosis of the shoulder joint, the capsule is split vertically and a large, curved osteotome is driven into the space between the head of the humerus and the glenoid As this groove in the bone is deepened the arm is externally rotated or adducted until the union is broken up Then it is abducted or rotated into the desired position If it is desired that the osteotomy be performed in the shaft of the humerus and this is usually in instances where one is afraid of lighting up old disease or where a rotation osteotomy is desirable, the incision is carried down to the bone below the joint, exposing the insertion of the subscapularis muscle in the inner edge of the bicipital groove This insertion is divided, the periosteum is stripped, and the bone is cut transversely with a curved osteotome When the bone has been severed, the lower fragment can be rotated outward on the upper fragment and then held in this position while the wound is closed with interrupted sutures

After the operation, whether the osteotomy has been done through the shoulder joint or through the proximal portion of the shaft of the humerus, the arm should be immobilized in a plaster of paris spica in the desired position The plaster should get a firm grip on the pelvis, should cover *both* shoulders, and should extend down the operated arm to the knuckles For arthrodesis the desired position is abduction of about 80° at the shoulder, forward flexion of 30°, and slight external rotation From such a position the hand may be brought to the face when the elbow is flexed

OPERATIONS ON ELBOW

Arthrodesis Arthrodesis of the elbow is seldom advisable, except in the case of patients who, as a result of chronic osteomyelitis or of severe fractures followed by infection or of tuberculosis, have suffered extensive destruction of the joint, and excision is usually preferable to arthrodesis There is no satisfactory operation for arthrodesis of the elbow In the cases in which I have performed this operation it has been done as follows

TECHNIC Through a lateral incision which begins about two inches above the joint and is carried down to the ridge on the humerus between the triceps and the supinator longus and the supinator brevis muscles and extended down across the joint and backward along the anterior border of the anconeus, the lower end of the humerus is exposed subperiosteally The lateral ligament and some periosteum is raised from the bone The head of the radius is excised, and soft tissue is sutured over the stump of the neck of the radius By adduction of the forearm the elbow joint is exposed Then the cartilage is removed from all of the joint surfaces

A number of osteoperiosteal grafts are obtained from the tibia These are inserted across the joint wherever possible, more of the grafts being placed anteriorly than posteriorly, some being placed on the inner side of the olecranon, between it and the inner condyle of the humerus Care is taken not to injure the ulnar nerve Just before the incision is closed, other osteoperiosteal grafts are placed across the outer side of the joint, bridging the space between the lateral border of the olecranon and the humerus and around the coronoid of the ulna Likewise, the space between the stump of the neck of the radius and the external condyle of the humerus is filled with bone chips

Postoperatively, the extremity is immobilized at an angle of approximately 135° at the elbow, with the forearm moderately pronated In instances in which there has been marked loss of bone, and in which there is a flail elbow which the patient is unable to control, a similar operation is performed except that more care is necessary in denuding the ends of the bone and

in placing the osteoperiosteal grafts In such instances I believe that fixation of the humerus to the ulna by one or two loops of stainless-steel wire is advisable Immobiliza tion should be continued for from three to six months [See also Chapter 14, with illus trations —Ed]

Arthroplasty The elbow lends itself to arthroplasty better than any other joint of either extremity We believe that a higher percentage of such procedures are successful here than in any other joint in the body, with the exception of the temporomandibu lar joints

Campbell s Technic [See Chapter 14 for illustrations —Ed.] With the patient re cumbent and the arm across the chest, and a tourniquet on the upper arm, an incision is begun from five to six inches above the elbow on the posterolateral surface of the arm This is carried downward, to pass be tween the external condyle of the humerus and the olecranon, to a point about one inch below the joint line The incision is carried down to the deep fascia Skin towels are ap plied Then the deep fascia is elevated to expose dorsally the aponeurosis of the tri ceps muscle This aponeurosis is severed transversely at its upper extremity and divided along its external and internal bor ders in order that it may be lifted as a flap the base of which is still attached to the olecranon process This fascial flap is ele vated, and the incision deepened in the mid line through the muscular fibers of the tri ceps to expose the humerus in its lower third The incision is carried through the periosteum With an elevator the perios teum is stripped from the lower third of the posterior surface of the humerus

The head of the radius and the olecranon process are exposed and the ulnar nerve is identified and protected from injury The bony fusion between the olecranon and the humerus is then severed with an osteotome and, if possible, the joint is flexed and dis located to the mesial side If there is union between the olecranon and the humerus and between the head of the radius and the humerus, this latter union must also be severed with an osteotome before the joint can be flexed and dislocated After the lower end of the humerus is delivered into the wound its surface is cut straight across, trimmed down with an osteotome until it is relatively thin, and then filed smooth with a wood file or rasp A straight hinge joint surface is made The olecranon fossa on the posterior surface of the lower portion of the humerus is deepened with a gouge The articular surface of the head of the radius is removed, and the greater sigmoid cavity of the ulna is deepened with a curved chisel or gouge The articular surfaces, having been denuded, are smoothed with a curved rasp or wood file

At this point the tourniquet is removed, bleeding vessels are clamped and tied, and the wound is packed with gauze while fascia lata is removed from the thigh, the latter having been prepared and draped before the operation started and covered with a towel The towel is removed, and an incision about eight inches long is made on the lateral surface of the thigh Care should be taken in making the incision not to cut through the fascia The incision is carried down to the fascia and the subcutaneous tissue is stripped back on each side A piece of fascia approximately seven inches long and four or five inches wide is excised The thigh wound is then fastened temporarily with skin clips or closed by an assistant while the surgeon re-exposes the elbow, sponges out the blood which may have col lected, re inspects the articular surfaces, and determines that the surface of the lower end of the humerus is at right angles to the shaft

A small hole from before backward is then drilled through the supracondylar ridge on either side of the humerus and the internal and external epicondylar ridges are excised so that the lower end of the humerus

is now considerably narrower from side to side than it was originally The strip of fascia is *then laid on the posterior surface* of the lower end of the humerus and folded over the end so that its middle lies on the anterior surface of the humerus Sutures are then passed through the drill holes on either side of the humerus and through the two margins of the strip of fascia and tied Then the fascia is reflected on itself and applied *to the lesser sigmoid fossa of* the *ulna* and over the articular surface of the head of the elbow has been ankylosed in more extension

In certain instances, I have not made a fascial tongue of the triceps aponeurosis, but have carried the incision down its lateral border, and then down over the olecranon, reflecting the tissue on the lateral side of the olecranon, and laterally from the humerus, thus exposing the joint through a lateral incision The bone is cut with a thin *osteotome which is directed transversely* In using this method special care should be

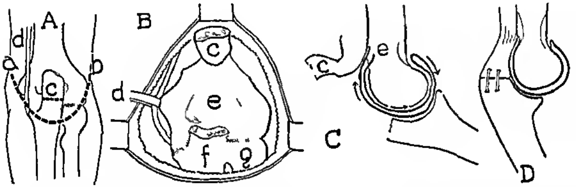


FIG 385 MacAusland elbow arthroplasty (A) Skin incision (a b), olecranon section (c), and ulnar nerve (d) View from behind (B) Exposure Olecranon fragment (c) *retracted upward, ulnar nerve* (d) *freed and retracted on tape, olecranon fossa* (e), and ulna and radius (f) and (g) (C) Method of passing fascial flap Retracted olecranon (c) and olecranon fossa (e) (D) Resuture of ulnar fragments to form double lined joint Original MacAusland procedure used only one fascial flap, that on the humerus

radius, the free end covering the articular surface of the olecranon process Campbell reflects part of this fascia down around the head of the radius I have not attempted to do this, but have excised the head of the radius and placed the sigmoid of the ulna more nearly in the center of the lower end of the humerus The margins of the fascia are sutured to the soft tissues, and the joint is then closed by reducing the dislocation of the bones and suturing the capsule from below upward, the elbow being held flexed at a right angle The flap of the triceps aponeurosis which has been severed at its upper end is sutured at a point lower than its former attachment, because, as a rule, taken to preserve the ulnar nerve It may be injured unless the tissues are pushed well away from the inner side of the lower end of the humerus before the osteotome reaches this area It may also be exposed through a short median incision and pulled out of the way *Zero chromic catgut is used by* Campbell for the fascia I usually use silk and sprinkle sulfanilamide powder in the wound before beginning to close the wound [See Chapter 22 in reference to this use of chemotherapy —Ed]

After the operation, the elbow is immobilized in plaster in a position of 90° of flexion This plaster is left on for two weeks At the end of this time it is bivalved, the

stitches are removed, and the patient is taught to begin to move the forearm actively and passively This is carried out at first three times a day and the bivalved plaster is used for a week or two longer As the arm becomes less sensitive it is carried in a sling A clove hitch is placed around the wrist and tied around the neck in order to increase the amount of flexion This clove hitch is loosened from time to time during the day and the elbow is permitted to go into as much extension as the patient can maintain without undue pain As the amount of movement increases and the pain decreases the patient may begin to use the arm practically The final result is not obtained until several months after the operation especially is this true where there has been marked atrophy of the muscles as a result of the ankylosis

TECHNIC OF McAUSLAND (Fig 385) McAusland s technic has the advantage that the operation is more easily performed However it has the disadvantage that the olecranon is cut through at its base Consequently nonunion of the olecranon may result in efforts to stimulate movement at the elbow joint

The elbow is approached through an inverted U incision which begins at the external condyle of the humerus passes upward around the tip of the olecranon *process and then curves downward to the* internal condyle of the humerus This incision is carried down to the deep fascia and the flap of skin and subcutaneous fascia is dissected downward Then a longitudinal incision is made in the deep fascia posterior to the internal condyle and the ulnar nerve is identified and raised from its bed A small piece of tape saturated with salt solution is passed around the nerve to hold it out of the way during the operation A transverse incision is now made through the deep fascia approximately one inch distal to the tip of the olecranon This is carried from the internal to the external border of the humerus The base of the olecranon is cut through with a saw or chisel, and the olecranon is lifted from its bed, separating it from the posterior surface of the humerus with a curved chisel if necessary, and reflected upward

With a thin blade osteotome the lower end of the humerus is then separated from the upper end of the ulna and the head of the radius, and the elbow is broken open by flexing it A quarter of an inch or more is then excised from each side of the lower end of the humerus, thus narrowing the lower end of the humerus by removing part of the epicondyles The lower end of the humerus is flattened and rounded from before backward and finished with a rasp or wood file until it forms a straight edge articular surface Then, either with a curved osteotome, gouge, or file, the sigmoid fossa in the ulna is deepened, and the humeral articular surface of the radius is fashioned so that its superior surface lies flush with that of the sigmoid of the ulna, thus forming a socket for the articular surface of the humerus

Fascia lata is then removed from the thigh and applied to the posterior surface of the lower end of the humerus, folded forward around it, and then reflected on itself and carried backward to be fitted into the greater and lesser sigmoids of the olecranon, and is brought out on the pos*terior surface of the joint This fascia is* sutured at its edges to the soft tissues or drill holes may be made in the humerus, as described by Campbell The elbow is closed by extending the joint Two small drill holes are made one through the proximal portion of the shaft of the ulna and another through the tip of the olecranon and with a piece of stainless steel wire the olecranon is fastened to its base The fascia which has been split transversely is then sutured and the skin and superficial fascia are brought down and sutured. The arm is fixed in circular plaster of paris in about 90° of flexion and the after treatment is carried out as described above

Operations for Increasing Range of Movement in Elbows Which Have Been Partially Ankylosed in Either Flexion or Extension but in Which Joint Movement Is Intact and in Which Limitation of Movement Is Due to Extra articular Fibrosis or Adhesions

Mobilization of Elbows Which Have Been Fixed in Flexion Either a lateral or an anterior incision may be used If the elbow is completely flexed a lateral incision is preferable This begins about three inches above the elbow joint just anterior to the epicondylar ridge and passes downward beyond the external condyle and backward along the anterior border of the anconeus muscle The incision is carried down to the bone and the supinator and flexor muscles of the forearm which lie anterior to the incision are lifted up from the lower end of the humerus and the capsule of the elbow joint Keeping close to the capsule and the periosteum, the incision is extended by sharp dissection inward across the joint to its inner side Then the capsule is divided transversely and the elbow is gradually extended

It is important that a fairly complete division of the anterior capsule be made and at times when the ankylosis in flexion is due to organization of an old hematoma in front of the elbow there may be a dense mass of fibrous tissue in front of the capsule which must be divided before extension is possible As much extension as can be obtained without undue force and without interfering with the circulation is obtained at the time of the operation and the arm is *immobilized in this position in circular* plaster of paris Further extension may be obtained by wedging plasters after the wound has healed and the sutures have been removed

In an elbow in which extension to beyond 90° is possible, but in which there is considerable limitation in extension, the anterior incision may be used This is made directly over the biceps tendon and carried straight down to the deep fascia, any large veins crossing the incision being ligated as they are exposed Usually this operation is done without a tourniquet in order to make no mistake in the identity of the brachial artery which lies close to the mesial border of the biceps tendon The biceps tendon is freed and is lengthened by the Z method its two ends being reflected The incision is carried down to expose the brachialis anticus and this short tendon is also lengthened by the Z method the lengthening extending somewhat up into the muscle tissue and its ends are reflected In exposing and lengthening the brachialis anticus tendon care must be taken not to injure the musculocutaneous nerve which lies lateral to and just beneath the biceps tendon

Having lengthened and reflected the ends of these two tendons close to their insertions into the radius and the ulna the soft tissues including the vessels and nerves, are gently separated from the anterior surface of the capsule of the joint by pushing them laterally and mesially in the depth of the wound When the capsule of the joint is satisfactorily exposed it is cut transversely so that the joint is opened widely on its anterior aspect This will usually permit quite free extension of the elbow The brachialis anticus and the biceps tendons are then sutured with as much lengthening as is necessary the two ends of the Z being slid by one another and united by medium silk The wound is closed and the extremity is immobilized in circular plaster of paris in as much extension as can be obtained without interfering with the circulation of the extremity If further extension is desired it can be obtained later by the use of a wedging plaster

Mobilization of an Elbow Which Has Been Ankylosed in Extension by Extra-articular Adhesions or Fibrosis The incision begins on the posterolateral aspect of the arm about five inches above the elbow

joint and extends downward close to the midline and passes along the outer border of the olecranon process and is carried through the deep fascia to expose the aponeurosis of the triceps muscle This aponeurosis is cut obliquely from each side close to the attachment of the muscle fibers at its upper end the two incisions coming together to make a V shaped tongue, point upward This incision is carried through the aponeurosis and the V shaped tongue is reflected down to its attachment to the olecranon The ulnar nerve is then identified by reflecting the subcutaneous tissue and skin on the inner side of the elbow, and is lifted out of its bed above the internal condyle Then a transverse incision is made in the capsule of the joint extending from the posterior border of the internal condyle across the joint to the posterior border of the external condyle and being curved slightly downward so that the attachments of the triceps muscle to the olecranon and the posterior capsule are included to permit free flexion of the elbow joint

The elbow is then flexed, using some force if necessary to tear any remaining adhesions in the posterior portion of the joint Then the ulnar nerve is replaced in its groove and the two borders of the triceps muscle are mobilized With the elbow maintained in a position of flexion the tongue like process of the triceps aponeurosis is laid back in place and sutured to the muscle on either side The space above, from which it has slipped down and where the margin of the muscle fibers are separated, is closed The subcutaneous tissues are then closed in layers and the limb is immobilized in circular plaster of paris in as much flexion as can be obtained without undue tension The plaster is left on for two weeks At the end of this time it is removed, and active and passive motion are begun

Excision of Head of Radius After old fractures, or after some cases of acute or chronic arthritis, rotation of the forearm is prevented by malformation of the head of the radius or by adhesions around this bone In such instances the head of the radius may be removed [See Chapter 31 for technic —Ed]

Osteotomy of Lower End of Humerus This operation is occasionally indicated in cubitus varus as a result of old injury to the elbow A lateral incision is used, the incision lying in the plane between the anterior border of the triceps muscle and along the supinators of the forearm posterior to the intermuscular septum, care being taken not to injure the radial nerve which crosses this septum in the upper part of the incision After the humerus is exposed, the periosteum is split longitudinally and stripped up on the anterior and posterior surfaces of the bone Then the humerus is divided with an osteotome, the point of division being just where the lower end of the shaft begins to expand to form the condyles A thin osteotome is u ed, care being taken not to drive the osteotome too far to the inner side and injure the ulnar nerve, which lies close to the ulnar border of the bone at this point When the humerus is nearly cut through it is broken by strong adduction of the arm

The wound is then closed in layers with fine silk, care being taken to maintain the position of the fragments, and the arm is immobilized in circular plaster of paris in a position of slight overcorrection, the elbow being fixed at an angle of 90° with the forearm fully pronated in order to abduct the lower end of the humerus This is a hanging cast type of plaster, supported from the wrist by a clove hitch which is passed around the neck [See Chapter 30 —Ed] The cast is left on for one week At the end of that time an x ray picture is taken in order to determine the position of the fragments If the position is not satisfactory it can be changed by cutting the plaster almost entirely around and wedging it in the direction desired At the end of two weeks a window is cut in the plaster and the sutures are removed, or the plaster may be

bivalved or may be removed and a new one applied

The hanging cast should be maintained for six weeks At the end of this time union should be sufficiently solid to permit the patient to carry the arm in a sling

OPERATIONS ON WRIST

Osteotomy for Flexion Deformity Occasionally the wrist becomes ankylosed in flexion as a result of a pyogenic or of a low grade infectious or proliferative arthritis In such instances there is usually marked atrophy of the bone and the patient may be in poor general condition Flexion deformity interferes with the function in the hand Consequently if the hand can be extended on the wrist to a position of about 30° in extension function will be markedly improved This is easily obtained by means of an osteotomy through the base of the styloid process of the radius

TECHNIC The vertical incision about two inches long lies on the volar side of the extensor carpi radialis tendon and is carried directly down to the bone The periosteum is split in a longitudinal direction and is stripped up on either side A small thin osteotome is driven straight across the radius, passing through the base of the styloid process and partly through the fused joint between the lower end of the radius and the first row of carpal bones There is little danger of harming any important structures When the bone is almost completely divided the osteotome is withdrawn and the wrist is forcibly dorsiflexed to correct the deformity to the desired degree The wound is then closed in layers and immobilized in the correct position in circular plaster of paris which extends from the middle of the arm to the base of the fingers The plaster is left on for from five to six weeks At the end of that time the plaster is removed, and the patient is encouraged to use the extremity

Operation for Synostosis of Radius and Ulna If the union of the two bones is in the upper portion between the head and neck of the radius and the ulna the operation for excision of the head of the radius may be used the offending portion of the radius being removed either with an osteotome or with bone cutting forceps After the operation the stump of the shaft of the radius is covered with surrounding soft tissue by means of a purse string suture and the exposed portion of the shaft of the ulna is smoothed off and any loose chips of bone are removed The incision is then closed in the usual way With synostosis between the shafts of the bones in their lower fourth—that is, if the lower two inches of the ulna is involved—it is probably wise to perform a pseudarthrosis of the ulna rather than attempt to remove the bone from between the two forearm bones This operation may also be used for synostosis at any level As a rule however in instances where synostosis occurs between the shafts of the radius and ulna above the lower fourth, a better end result will be obtained if the synostosing bone is removed and if the shafts of the forearm bones are left intact

TECHNIC OF EXCISION OF SYNOSTOSIS The posterior surface of the shaft of the ulna is approached by a longitudinal incision over the extensor carpi ulnaris muscle, the incision being of ample length and its center being over the site of the synostosis The extensor carpi ulnaris is retracted to the radial side to expose the posterior surface of the shaft of the ulna and by sharp dissection the incision is carried radialward across the synostosis and the interosseous membrane, keeping between the muscles and the bone formed in the interosseous membrane lifting up the origins of the forearm muscles where they are encountered over the synostosis If possible the periosteum is not removed from the synostosis

After the tissues have been retracted to the radial side to expose the shaft of the radius, the synostosis is outlined and the interosseous membrane at either end of it is excised It is then cut across with a small,

sharp osteotome and is removed piecemeal, either with an osteotome or with rongeur and bone-cutting forceps If possible, all of the intervening bone should be removed After its removal the space between the bone may be filled with a mass of subcutaneous fat removed from the thigh or a strip of fascia may be wrapped around the shaft of the ulna in order to prevent recurrence of the synostosis As a rule, however, if an adequate removal has been effected the interposition of transplanted tissue is not necessary to prevent a recurrence Subcutaneous tissue and fascia are closed with interrupted sutures of fine silk and the skin is closed with continuous sutures As a rule, no plaster is necessary, and movement is started as soon as the wound has healed—that is, in about two weeks

Pseudarthrosis of Ulna This is the operation of choice in synostosis of the lower portion of the radius and the ulna or in ankylosis of the inferior radio-ulnar joint [It is the considered opinion of many men that this procedure for ankylosis of the inferior radio ulnar joint is inferior to subperiosteal resection of the ulnar head See Chapter 32 —Ed] The ulna is exposed about two inches above the wrist by a posteromesial incision along the border of the extensor carpi ulnaris muscle This muscle is retracted to the radial side and the incision is made sufficiently long so that by retracting to the palmar aspect the entire shaft of the ulna can be exposed Then the periosteum is cut around the entire circumference of the ulna at two points, approximately one-half of an inch apart A Gigli saw is introduced between the two bones and approximately one half of an inch of the shaft of the ulna is resected The wound is closed in layers and a plaster of paris cast is applied and left on for two weeks until the wound is healed At the end of this time the cast is removed and the patient may begin to use the extremity gradually

Technic of Arthrodesis of Wrist. A longitudinal incision approximately six inches long is made on the dorsum of the forearm just to the ulnar side of the common extensor tendons of the fingers This incision lies between the extensor proprius of the fifth finger and the common extensor tendon of the fifth finger It is carried down to the bone and through the dorsal carpal ligament and reaches the lower end of the radius near its ulnar side The incision is carried down along the radial border of the extensor of the fifth finger as far as the base of the metacarpal bones and the periosteum is excised over the proximal portion of the fourth metacarpal Then a broad, thin osteotome is introduced and a thin layer of bone is raised from the posterior surface of the radius and the posterior surfaces of the carpals and metacarpals, the osteotome being directed to the radial side and keeping just beneath the cortex of the bones This lifts a flap resulting in exposure of the radiocarpal joint and of most of the carpal and carpometacarpal joints The carpometacarpal and the carpal joints on the ulnar side of the incision can be exposed by raising a thin sliver of bone from the dorsal surface of the bones to the ulnar side, care being taken not to interfere with the radio ulnar joint which if possible is not opened

Having opened the joints, the articular cartilage is removed with a small curette or with a thin osteotome or gouge and some bone chips are packed in between the carpal bones and the lower end of the radius and between the bones forming the first row of the carpus where space permits Then a thin, flat graft of bone is removed—either from the posterior surface of the ilium according to the technic of Abbott, or a thin, wide, flat osteoperiosteal graft from the tibia—and is curved slightly so that it will fit in the prepared space when the wrist is dorsiflexed This is slipped under the layer elevated from the dorsal surface of the lower end of the radius and from the carpals and metacarpals, reaching to a point approximately one half of an inch beyond the base

of the metacarpal bones and approximately one and one half inches proximal to the lower end of the radius The elevated flap is then laid over it the wound is closed in layers and the extremity is immobilized in circular plaster of paris which extends from the middle of the arm down to the tip of the fingers with the forearm in a position of slight pronation and the wrist dorsiflexed about 30° This plaster may be left on for two months or it may be changed at the end of two weeks for a more snugly fitting one which extends only to the base of the fingers in order to permit movement of the fingers and thumb The second plaster is left on for six weeks at the end of which time a firm ankylosis should be present The plaster may then be removed and the patient may begin to gradually use the extremity

[See also Chapters 14 and 33 and illustrations.—Ed]

Excision of Semilunar Bone The semilunar and the scaphoid are sometimes removed either for old fractures of either bone or for chronic osteitis either Kienbock s disease of the semilunar or Preisser s disease of the scaphoid The incision is made on the dorsum of the wrist to the ulnar side of the extensor longus of the thumb and between this and the extensor tendon of the index finger The incision is about two inches long and its center lies just below the wrist joint It is carried down through the annular ligament directly to the bone and by sharp dissection the posterior surface of the adjacent carpal bones is exposed and their posterior ligaments are cut

At this point it is advisable to identify the bone which it is desirable to remove as it is quite possible to confuse the semilunar bone with the adjacent half of an old fractured scaphoid or vice versa In some instances both bones are removed intentionally it being believed by some surgeons that when one of these two bones is removed either both or the entire proximal layer of carpal bones should be removed The choice as to how much bone should be excised from the first row of carpals is one which rests with the individual surgeon It is to be noted that the above incision comes directly down on the mesial or ulnar side of the scaphoid and that the semilunar bone lies to the ulnar side of the incision It is perhaps for this reason that the wrong bone is sometimes removed

Having identified the offending bone the dorsal tendons over it are retracted and by sharp dissection its entire dorsal surface is freed from ligamentous attachments Then the wrist is strongly flexed and a knife is slipped between the bones and some of the volar ligaments are cut A rather thin skid or bone chisel or other strong instrument is then slipped between the bones and while the wrist is strongly flexed the semilunar or scaphoid as the case may be is pried out In instances where this operation is done for an old fracture of the scaphoid with traumatic arthritis after the posterior portion of the scaphoid is removed the anterior portion can be excised by deep dissection or if necessary through a separate incision on the lateral side of the wrist If this second incision is made special care should be taken not to injure the radial artery and the dorsal branch of the radial nerve which lie in the anatomic snuffbox The artery shows considerable variation in position

After the bone has been removed the wound is closed in layers suturing the dorsal ligament with fine silk and the wrist is immobilized in circular plaster of paris which extends from the upper portion of the forearm to the base of the fingers This is worn for from two to four weeks and is then removed and the patient is encouraged to use the hand

Excision of a Dislocated Semilunar Bone Sometimes an old dislocated semilunar bone which lies in the volar aspect of the wrist beneath the flexor tendons is encountered [See Chapter 33 for technic —Ed]

OPERATIONS ON FINGERS

Stenosing Tenosynovitis of Extensor or Abductor Tendons of Thumb This is a condition which may persist over a period of many months and cause considerable pain over the radial styloid and disability and may not yield to conservative treatment which consists of immobilization of the thumb in abduction In such instances the tendon sheaths should be opened

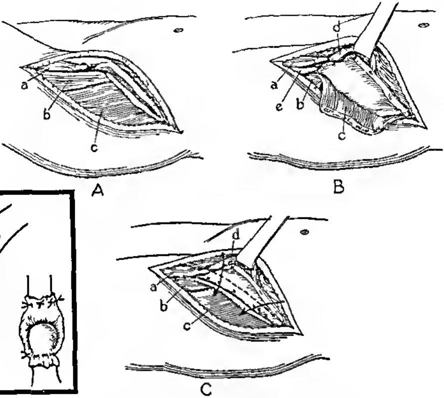
TECHNIC The operation is best done under local anesthesia as it is important to determine by palpation the exact site of the painful lesion Then an incision about two inches long is made through the skin directly over the tender point (radial styloid) and carried down to the tendon sheath care being taken in case the abductor and short extensor tendons of the thumb are involved not to injure the dorsal branch of the radial nerve which supplies the back of the thumb The tendon sheath is opened by a longitudinal incision and the tendon is lifted out and inspected Any excess granulation tissue which may be present on the tendon or sheath is removed The tendon sheath is left open and the wound is closed in layers and dressed with a bandage which holds the thumb in extension and abduction for a week At the end of this time the sutures are removed and the patient may begin gradually to use the hand

Operation for Trigger or Snapping Finger This is due to a stenosing tenosynovitis of one of the flexor tendons of the fingers or of the thumb The stenosis usually is in the palm just proximal to the base of the phalanx It is important before operating to locate as accurately as possible the site of constriction Then under local anesthesia the offending tendon is exposed the sheath is split and it will usually be found that a bulb like enlargement on the tendon is present If the sheath is widely split and left open it will not be necessary to remove this enlargement or to attempt to decrease the size of the tendon The wound is then closed in layers and the hand is dressed with the tendons immobilized for a week At the end of this time the sutures are removed and the patient may begin to exercise the hand

Posterior Capsulotomy for Stiffness of Fingers in Extension at Metacarpophalangeal Joints An incision is made on either side of the joint and is carried directly downward to the ligamentous structure between the heads of the metacarpals Then the joint capsule is incised on its lateral aspect on either side The subcutaneous tissues and tendon are dissected from the dorsal joint capsule and lifted up and the joint capsule is cut across in its posterior portion Then the joint capsule on the lateral and mesial aspect of the involved joint is cut across almost to the palmar aspect of the metacarpal head the soft extracapsular tissues being elevated by blunt dissection This will permit flexion of the fingers but with flexion there is a tendency of the extensor tendon to snap over to one or the other side of the metacarpal head The incision is closed in layers and the wound is dressed with the fingers moderately flexed This flexion is increased with a banjo splint and traction or by further flexing the fingers in a bandage dressing covered with strips of adhesive applied at the end of a week after deep structures have begun to heal [The banjo splint is usually preferred —Ed]

Technic of Arthroplasty of Metacarpophalangeal Joints An incision about two inches long and centered over the joint is made on the dorsum of the hand and finger lying between the metatarsal heads and is carried obliquely downward and inward or outward to the joint capsule. This is split the periosteum is lifted up for a short distance on either side of the joint and the bones if ankylosed by bone are divided with a small osteotome Then the head of the metacarpal is reduced in size and rounded and likewise the base of the phalanx is reduced in size and hollowed

slightly from before backward so that its surface corresponds roughly to the curve of the head of the metacarpal, sufficient bone being removed so that with moderate traction the two bones are separated approximately one fourth of an inch wound is then closed in layers and the hand is immobilized in a splint for a period of two weeks At the end of this time the splint is removed and slight movement is begun This is gradually increased If considerable stiffness in extension or flexion is present,



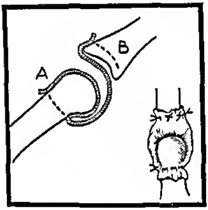


FIG 386 (*Left, in square*) Finger arthroplasty (A) Line of pursestring, (B) line of suture for fascial sheet in cross section Inset represents posterior view of reconstructed joint

FIG 387 (*Right*) Release for hip flexion deformity (A) (a) Sartorius, (b) tensor fasciae femoris, (c) gluteus medius separated from anterior superior spine and iliac crest with thin layer of bone Iliacus reflected from inner face of ilium (B) Flexion corrected after separation of rectus from anterior inferior spine (a) Sartorius, (b) tensor fasciae femoris, (c) gluteus medius, (d) iliacus, (e) rectus (C) Dotted line represents resected portion of ilium, x line represents area of bone roughened by curette for reattachment of muscles Arrows indicate suture of subcutaneous tissue of upper skin flap to deep fascia (a) Sartorius, (b) tensor fasciae femoris, (c) gluteus medius, (d) iliacus

A thin strip of fascia lata from the inner side of the thigh or from the arm over the biceps muscle is removed, folded from behind forward over the head of the metacarpal bone, and tied with a purse string suture The free end of the fascia is brought back out between the two bones, and sutured to the base of the phalanx (Fig 386) The this can be partially overcome by the temporary use of a banjo splint during convalescence

Arthroplasty of Fingers Arthroplasties of the fingers are not, as a rule, successful Occasionally, however, a satisfactory result is obtained and the operation should not be denied patients who desire it and who have

had its limitations explained to them beforehand

TECHNIC The finger is exposed through a dorsolateral incision similar to that described for drainage (see p 426) However, the incision is longer and is carried approximately two-thirds of the distance toward the joints on either side, directly down to bone The tissues on either side are then reflected by sharp dissection, and the remains of the joint capsule are cut across transversely If the bones are ankylosed by bone, they are divided by a small, thin osteotome The head of the proximal phalanx is then rounded and the base of the distal phalanx is so shaped that it is curved from before backward and fits roughly the curve on the head of the proximal phalanx Sufficient bone is removed so that approximately one fourth of an inch separation of the two bones is present when moderate traction is applied to the end of the finger Then a thin strip of fascia from the inner side of the thigh is removed and placed around the head of the proximal phalanx, the free end of the strip being on the back It is folded over on to the volar surface and brought back again and sutured to the tissues covering the dorsum of the distal phalanx, as in metacarpal arthroplasty above, interposing two strips of fascia between the ends of the bones

The finger is immobilized on a splint for a period of two weeks At the end of this time the splint is removed and movement is begun If it seems unusually stiff an attempt may be made to increase the range of movement by means of a banjo splint and elastic traction

SURGERY OF HIP

Fasciotomy for Extra articular Ankylosis in Flexion (Fig 387) An incision beginning over the crest of the ilium and slightly below it approximately two or three inches posterior to the anterior superior spine is carried forward along the crest of the ilium to the anterior superior spine and then downward over the anterior surface of the thigh along the lateral border of the sartorius muscle between this muscle and the tensor fascia femoris The incision is carried down to the bone and to the deep fascia on the thigh The tensor fascia femoris and sartorius muscles are removed from their origin and the periosteum adjacent to the crest of the ilium is cut With a rather sharp periosteal elevator the origin of the gluteus maximus muscle is stripped in its anterior portion for a distance of about two inches so that this muscle slides downward and backward At the same time the periosteum is removed from the crest of the ilium and from its inner aspect under the iliacus with a sharp periosteal elevator, thus permitting the anterior superior spine and a portion of the crest of the ilium to project in the wound As a rule, this will permit extension of the thigh to a considerable degree Occasionally, however, there is marked contracture of the capsule of the joint in its anterior portion

If the thigh cannot be quite freely extended after the above procedure has been completed, the dissection should be carried down to the joint, extending the dissection down along the anterior border of the ilium When the hip joint is reached the anterior portion of the capsule should be cut across parallel with the femoral neck, dividing the Y ligament and the reflected tendon of the origin of the rectus femoris muscle As a rule, this will permit full extension of the hip The projecting portion of the ilium, including the anterior superior spine and the adjacent portion of the bone, is then cut off so that it does not project forward in the wound The wound is then closed in layers, making no attempt to re attach the muscles to their bony origin

Occasionally, in severe cases, it is necessary to sever the iliopsoas muscle near its insertion into the lesser trochanter before extension of the hip can be obtained If there is much adduction deformity, this may be corrected by tenotomy of the ad

ductor muscles after the above operation has been completed

CAMPBELL'S TECHNIC The incision and operation are similar, except that instead of denuding the anterior superior spine of its muscle attachments a thin layer from the outer portion of the crest of the ilium is cut off with an osteotome before the muscles are stripped from the outer side of the bone This thin portion of the crest and the anterior spine is then reflected outward and the muscle stripping is carried out Likewise, the stripping of the inner side of the ilium, lifting up some of the origin of the iliopsoas muscle, is carried out and if necessary the dissection is carried down to divide the deeper structures including the rectus femoris tendon, the capsule of the hip, and the iliopsoas muscle

After correction has been obtained a tract of bone one inch wide is denuded on the side of the ilium two inches below and parallel to the former crest Then the thin strip of iliac crest and anterior superior spine which was lifted up with the attachment of the gluteus medius muscle is shifted downward and approximated to this denuded area The incision is enclosed by suturing the superficial fascia on the upper side of the incision, the deep fascia on the lower side, thus bringing the skin incision one inch below the edge of the ilium, and avoiding pressure from underlying bone

AFTER TREATMENT After fasciotomy by either of these methods the hip may be placed in hyperextension and abduction and immobilized in a plaster of paris spica which extends from the toes to the nipple on the affected side and to the knee on the opposite side, or the patient may be placed in bed with a fracture board under the mattress and moderate traction to the extremity In instances where there has been severe deformity it is believed that the traction method of after treatment is less liable to lead to shock and gradual correction can be obtained postoperatively In attempting gradual correction by traction, either with or without a Thomas splint, it is frequently necessary to fix the opposite limb in flexion with the knee extended in order to immobilize the pelvis and lumbar spine Otherwise, traction will merely pull the pelvis down with an increased lumbar lordosis

Oblique Osteotomy of MacMurray (Fig 388) This procedure is used for the relief of hypertrophic arthritis of the hip, and in ununited fractures of the femoral neck The incision begins on the lateral side of the thigh opposite the tip of the trochanter and is extended downward for

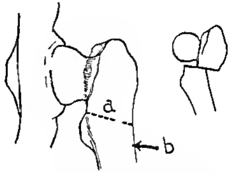


FIG 388 MacMurray's osteotomy (a) indicates line of bone section Arrow (b) indicates direction of displacement of shaft Inset shows shaft being displaced beneath head

a distance of about five inches and is carried through the deep fascia to the lateral aspect of the femur The proximal fibers of the vastus lateralis muscle and the periosteum are split laterally just below the trochanter Then the tissues over the front of the femur are reflected upward and mesially, so that the lower border of the neck of the femur and the lesser trochanter can be palpated This is done by blunt dissection

After the position of the lower border of the neck and of the lesser trochanter are located, a line is projected outward and downward from the space between the former and the latter to the lateral surface of the femur This will reach the lateral border of the shaft at a position about one inch below the base of the trochanter This line lies at an angle of approximately 45°

to the long axis of the shaft of the femur The femur is then cut obliquely at an angle of about 45°, beginning on the outer surface of the shaft so that the mesial side of the osteotomy emerges between the lesser trochanter and the lower border of the neck The femur is completely divided Then, by abduction and also by means of a large periosteal elevator or bone skid which is inserted between the fragments the distal

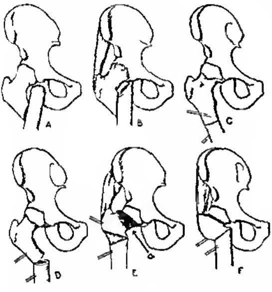


FIG 389 (A) Lorenz bifurcation, (B) Hass osteotomy (C) and (D) low Schanz osteotomy (E) and (F) high Schanz osteotomy, in (E) the shearing strain in a nonunion is indicated at (a) and its elimination shown in (F)

fragment is forced inward it is displaced inward approximately one half the diameter of the shaft of the femur at the point of the osteotomy The wound is then closed while the extremity is held in a position of moderate abduction and flexion and a plaster-of paris spica is applied from the toes to the pelvis, or, if the pelvis cannot be fixed in the plaster, it should extend up to the armpits with the limb immobilized in a neutral position as regards rotation and 30° of flexion and abducted about 20° The spica is left in position for from six to eight weeks At the end of this time it is removed, and the patient begins to exercise the hip and loosen up the knee. The patient is gotten out of bed on crutches from two to four weeks later, and the crutches are discarded as union becomes more firm and strength returns to the extremity

[The following three osteotomies were originally designed for irreducible congenital dislocations of the hip and are so described here They have all been adapted to the problem of arthritis of the hip and of ununited fracture of the neck of the femur In the Lorenz bifurcation and the Haas modification of it, when so used, the shaft is displaced toward the ischium and beneath the acetabulum, instead of into the acetabulum All three of these osteotomies are low osteotomies, both trochanters being with the upper fragment In this country, however, the high osteotomy of MacMurray has largely replaced them in these conditions The gooseneck fixation appliance devised by Moore and Blount has made postoperative plaster fixation unnecessary with the MacMurray type of osteotomy —Ed]

Bifurcation Osteotomy (Lorenz and Haas) (Fig 389) The site of the osteotomy is at the level of the acetabulum A lateral incision begins at the tip of the trochanter and extends downward for a distance of about six inches The deep fascia is divided, and the lateral surface of the femur is approached subperiosteally through the fibers of the upper portion of the vastus lateralis muscle The original Lorenz osteotomy consisted of an oblique osteotomy in an upward and inward direction as viewed from the front The shaft was then displaced into the capsule-covered acetabulum while the raw surface of the proximal fragment was placed in contact with the shaft

Haas modified this osteotomy so that instead of being oblique in one plane the femur was divided in an oblique frontal plane from below posteriorly to above anteriorly to provide a relatively large area of contact of raw bony surface and to prevent

flexion of the upper fragment with possible injury of the femoral vessels The proximal end of the osteotomy is opposite the acetabulum, the lesser trochanter being included in the proximal fragment Haas inserts a drill from below posteriorly to above anteriorly toward the acetabulum in order to determine the direct line of the osteotomy The roentgenogram is then made to insure the correct position The shaft is then divided in this plane with an osteotome The distal fragment is then abducted so that its proximal end rolls inward, upward, and anteriorly into the acetabulum, and the portion of the raw surfaces of the two fragments remains in contact with a layer of capsule interposed between the sharp end of the distal fragment and the articular surface of the acetabulum The wound is then closed and the leg is abducted to 30° and slightly flexed and is immobilized in a single plaster-of paris spica, which extends from the toes to the nipple, for a period of eight weeks At the end of that time the spica is removed, and exercises are begun to restore movement in the knee and hip Four weeks later the patient is gotten up on crutches

Schanz Osteotomy (Fig 389) This is an osteotomy which angulates the upper fragment inward against the pelvis while the lower fragment is parallel to the weight bearing line of the extremity Also, the weight bearing line is shifted inward The femur is approached through a long, lateral incision after it has been determined at what angle the bone is to be bent after the osteotomy The most desirable point for the osteotomy is at the level of the tuberosity of the ischium

Before the osteotomy is performed the leg is fully adducted, and an x ray is made in order to determine what angulation of the femur is necessary in order that the proximal fragment approach the side of the pelvis From the angle thus calculated it is possible to determine the angle at which the large Gaenslen screws are drilled into the bone After the side of the femur has been exposed these two large screws are drilled in the bone at such an angle that when the lower fragment is abducted after osteotomy—that is, bowed inward while the upper fragment is held in the adducted position—the two screws will be parallel They are placed in the bone from two and one half to three inches apart, the lower one being at right angles with the shaft of the femur while the upper one makes an angle with the shaft equal to the angle which it is proposed to create, usually approximately 20° After these two pins are in place a transverse osteotomy of the femur midway between them is performed at the level of the tuber ischium with an osteotome and the lower fragment is abducted to the desired degree until the two pins are parallel Then the two pins are fixed with plates or clamps to maintain the angulation The wound is then closed and the extremity is immobilized in a plaster of paris spica

As soon as the plaster is set a window should be cut in it around the pins and plates, as it is not desirable that these be fixed in the plaster, because movement of the patient in the plaster is apt to loosen the fragments when the pins are fixed to the plaster Immobilization is continued for approximately ten weeks At the end of this time the plaster and pins are removed and the patient may begin to exercise the leg and is gotten up on crutches from two to four weeks later

Subtrochanteric Osteotomy The above osteotomies are used where there is not bony ankylosis between the upper end of the femur and the pelvis Where such ankylosis is present the proximal extremity is fixed and all that is necessary is a subtrochanteric osteotomy This may be performed through a short lateral incision just wide enough for the introduction of the osteotome so that the osteotomy is performed subcutaneously In this method an incision one inch long is made just below the trochanter A broad osteotome is introduced down to the bone, is then rotated 90°, and is driven almost

two thirds of the way through the bone Then the bone is fractured by forcible adduction and brought out into the desired position

I prefer the open method An incision about four inches long beginning one inch above the tip of the trochanter is made on the lateral surface of the thigh and is carried down to the lateral surface of the femur and the anterior surface of the bone is exposed to locate the inferior border of the neck and the lesser trochanter The bone is then cut through with an osteotome As a rule the entire section is not made, but a portion of the inner cortex is broken by adducting the hip Sometimes a wedge of variable size is removed from the outer portion of the shaft in the trochanteric region of the femur in order to prevent displacement At other times a V shaped or curved osteotomy is performed In this instance the incision is carried more anteriorly so that the anterior surface of the femur is exposed The V-shaped osteotomy is used because there is less danger of slipping of the fragments when the leg is abducted However, execution is a little more difficult

After the operation the leg is abducted and if a flexion deformity is present, it is corrected as much as can be done without causing displacement of the fragments Then the adductor muscles are sectioned with a tenotome, if this is indicated The leg is then immobilized in a plaster of paris spica which extends from the toes to the nipples in the corrected position If it has not been possible to obtain adequate correction at the time of the operation without danger of displacing the fragments, the limb is left in plaster for two weeks At the end of this time the spica is removed, further correction is obtained, and a new spica is applied The immobilization is continued for from eight to ten weeks At the end of this time the spica is removed and the patient begins to exercise the limb in bed to loosen up the knee and ankle At the end of from two to four weeks after removal of the spica, the patient is gotten up on crutches, which are discarded as soon as the leg is strong enough to get along without them

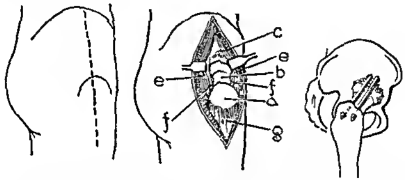


Fig 390 Autogenous bone peg arthrodesis of hip (*Left*) Line of incision (*Center*) Exposure (a) Trochanter, (b) head and neck of femur (c) acetabular margin, (e) divided and retracted gluteus (f) edges of divided capsule (g) vastus lateralis (*Right*) Pegs are shown placed through trochanter along denuded head and neck and embedded in ilium, with bone chips placed at junction of head and acetabulum

Arthrodesis of Hip The large number of methods for arthrodesis of the hip is evidence that it is difficult to obtain union in this joint, due largely to the long lever of the femur and the great strain which is put upon the joint and to the relatively small articular surface In old arthritic joints the articular surfaces are composed of eburnated bone which will not grow together

Consequently arthrodesis in these joints is especially difficult and should consist of both intra and extra articular methods and should not be undertaken except in relatively young and robust individuals Since an attempt is to be made to render the hip stiff there is no necessity of retaining the nerve supply to the tensor fascia femoris and the anterior portion of the gluteus medius muscle Consequently the side of the ilium can be approached through a lateral incision above the trochanter Likewise an anterolateral incision which passes posterior or lateral to the tensor fascia femoris may be used or the routine anterolateral incision of Smith Petersen may be used

I shall describe briefly three methods

Autogenous Bone Pegs (Fig 390) A lateral incision is made on the side of the pelvis extending from above the trochanter downward to about three inches below the base of the trochanter This is carried down to the femur the fascia above the trochanter is split in a vertical line and the fibers of the gluteus medius muscle are separated down to the side of the ilium Then the insertion of this muscle into the upper end of the femur is dissected free on either side of the trochanter to free the upper end of the femur and permit retraction of muscles forward and backward to expose the side of the ilium and the upper portion of the hip joint

The capsule of the joint is then opened and a large square section which includes the superior portion of the cotyloid ligament is removed In this way the upper surface of the neck of the femur and the superior portion of the joint are exposed With an osteotome the articular surfaces of the femur and of the ilium in the upper part of the joint are removed and this area is packed with bone chips Two drill holes with a one-quarter inch drill are made through the trochanter and extending along the upper portion of the neck of the femur into the ilium just above the acetabulum Into these holes are driven two autogenous grafts removed from the tibia and approximately one quarter of an inch in diameter the square pegs fitting tightly into the round hole These grafts project into the ilium approximately one half of an inch The space between the grafts and the upper end of the femur at the side of the ilium is filled with bone chips which are removed from the ilium The grafts are inserted while the hip is held in a position of abduction to 15 or 20°

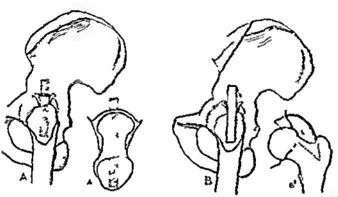
The wound is then closed in layers and the extremity is immobilized in a plaster of paris spica At the end of four weeks if the plaster has become loose it is removed and the wound is dressed and a skin tight spica is applied I have found that this operation can be performed with considerably less shock than can the operations through the anterolateral route and in my hands it has been more successful

Method of Ghormley (Fig 391) The hip is approached through the anterolateral incision of Smith Petersen the patient lying on the side with a sandbag under the hip and one under the knee so that the thigh is slightly adducted and slightly flexed The incision is made over the crest of the ilium beginning about one third of the way back and extending forward to the anterior superior spine At this point it turns downward along the anterolateral surface of the thigh between the sartorius and tensor fascia femoris muscles The incision is carried down between these muscles to the anterior inferior spine of the ilium Then the periosteum along the crest of the ilium is cut and the anterior portions of the gluteus medius and minimus muscles and the tensor fascia femoris are elevated subperiosteally from the ilium Likewise the sartorius is elevated from the anterior superior spine and the iliacus muscle is subperiosteally stripped from the inner side of the pelvis in the region adjacent to the anterior superior spine The incision is then carried down to the hip the capsule of

the hip joint is opened and the articular surfaces are denuded of cartilage

The superior surface of the neck of the femur and the side of the ilium are bared of periosteum, and a groove is cut in the side of the pelvis extending through the rim of the acetabulum and a similar groove is cut in the superior surface of the neck of the femur Then a large triangular piece of bone including the anterior superior spine and the adjacent portions of the ilium, maintained in order not to displace the graft

After the wound is closed the sandbag is gently removed, the patient (already upon a fracture table) is placed upon his back, and a plaster of paris spica is applied which extends from the toes to the nipples and maintains the limb in a position of moderate abduction At the end of from two to four weeks this should be removed, the wound dressed, and a new skin tight plaster applied



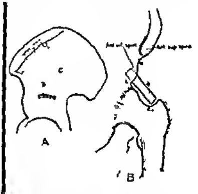


FIG 391 (*Left*) Ghormley hip arthrodesis Dotted line in (A) shows portion of iliac crest to be removed for use as graft, opening in capsule, and extent of trench for graft. (A') represents extent of trench seen from above (B) and (B') show placing of graft completed

FIG 392 (*Right*) L Episcopo bone block for hip (A) shows trench (a) for reception of graft into ilium (c) above acetabulum It slopes upward Graft may be removed as designated by (a) or (b) (B) shows operation completed Graft is put in with hip in adduction and is long enough to prevent abduction beyond neutral

is so cut that its edges fit into these two grooves when the hip is in the desired position The hip is then adducted The large free graft from the ilium is placed in the groove in the acetabular rim and the hip is abducted to bring it in place in the groove in the femoral neck The space in the joint and around the graft is then packed with bone chips and the wound is closed in layers, heavy sutures being necessary to hold the large muscle flaps in position These are passed through the deep fascia and the origins of the tensor fasciae femoris and sartorius are brought together over the denuded bone While the wound is being closed the position of the leg must be carefully in order to secure more efficient immobilization This is worn for at least three months. At the end of this time it is removed, and if union is quite solid the patient may begin to exercise the knee in bed If union is not solid, the spica should be replaced for six weeks longer As soon as the limb is sufficiently strong and solid, the patient may get up on crutches which can be discarded as soon as the leg is strong enough to use without them

WATSON JONES METHOD This method is used especially for patients with malum coxae senilis In patients who are good surgical risks an intra articular arthrodesis is first performed Then from 10 to 14 days

later a large Smith Petersen nail made of 3 mm steel and being 15 mm wide and from 4¾ to 5½ inches long is used to fix the hip In patients who are not good surgical risks—that is, patients who are over 60 years of age—Watson Jones has immobilized the hip joint by the use of the nail alone without postoperative support The technic of the insertion of the nail is as follows

Any adduction deformity is corrected if necessary, by tenotomy of the adductors, and the rotation deformity, if present, is corrected as much as possible The patient is placed on the table with the malleoli touching—that is with the leg straight—and if shortening is present only the minimum degree of abduction necessary to correct the shortening is used The hip is not deliberately flexed A two inch incision is made over the shaft of the femur, the center of the incision being just below the distal margin of the greater trochanter A strong guide wire is inserted along the axis of the neck and x rays are made in two planes The wire should lie precisely in the middle of the neck in the lateral view and in the anteroposterior view it should traverse the neck in such a line that it will emerge in the roof of the acetabulum and point at the lower part of the sacro iliac joint If the wire is not in satisfactory position, other wires are inserted and new x rays are made until a wire is obtained which is in satisfactory position Then the long nail is driven home parallel with the wire and a cross pin is inserted through its head to prevent displacement The nail should pass through the head of the femur and extend into the ilium for a distance of one inch or more

After treatment If there is any suspicion of splitting of the head of the femur, a short plaster of paris spica is applied for the first few weeks Otherwise, no plaster is used and the patient is permitted to be up from within ten days to two weeks after the operation and discards his crutches as soon as he is able to do so

Bone Block of L'Episcopo for Painful Hip (Fig 392) With the patient lying flat upon the table near the edge, the hip is exposed by the Smith Petersen incision as described under arthrodesis of the hip—Ghormley (p 455)

If there is considerable new bone present at the upper margin of the acetabulum a curved graft is taken along the natural curve of the ilium, starting just behind the anterior superior spine and going backward until the desired length can be removed The graft should be one and one half inches wide and should be sufficiently long to reach from a slot in the side of the ilium to the trochanteric fossa when the hip is in the neutral position The graft should include the cortex and some of the cancellous portion of the ilium, that is, it should be fairly heavy

Preliminary to taking the graft, a slot is cut in the side of the ilium and its superior margin is undercut and lifted up so that the end of the graft will fit under the flap of bone Then the measurement from the depth of this slot to the fossa at the base of the trochanter is taken This is the length of the graft After the graft has been cut the thigh is adducted, one end of the graft is slipped under the slot, and the other end is placed between the fossa in the trochanter and the neck of the femur Then the femur is abducted to the neutral position, thus jamming the graft into the slot and impinging it against the fossa mesial to the trochanter The wound is then closed and the hip is immobilized in the neutral position in plaster of paris which extends from the nipple line to the toes on the affected side This cast is left on for from six to eight weeks when it is changed to a short spica and the patient allowed to walk with crutches Complete weight bearing is permitted as soon as x ray examination shows union of the grafts to the ilium, usually in from 10 to 12 weeks after the operation

Acetabuloplasty (Smith-Petersen) (Fig 393) The incision begins over the

anterior crest of the ilium and extends forward to the anterior superior spine It is then curved downward along the lateral border of the sartorius muscle, for a distance of about four inches The incision down the thigh is carried between the lateral border of the sartorius and the tensor fascia femoris muscles through the deep fascia to expose the anterior inferior spine The incision along the crest is carried down ward When the anterior margin of the acetabulum and the anterior portion of the capsule of the hip are exposed the tendon of the rectus muscle is detached by a Z tenotomy on the flat, and reflected downward Then, with a large osteotome a section of the anterior and superior wall of the acetabulum is removed The wide osteotome is placed against the lip of the acetabulum and parallel to the neck of the femur with the

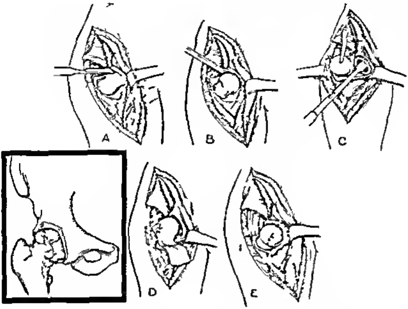


Fig 393 (*Left, boxed*) Smith Petersen acetabuloplasty
Fig 394 (*Right*) Fascial arthroplasty of hip (A) Osteotome definition of proposed joint line, (B) curved osteotome or gouge definition of head outline, (C) reaming of acetabulum and rounding of head by Murphy male and female instruments, (D) fascial envelope about head, (E) suture of fascial envelope to tissues about acetabular rim before reducing head

to the bone and the anterior portion of the gluteus medius stripped from the bone subperiosteally to expose the lateral surface of the ilium and to permit retraction of the lateral side of the wound The sartorius is detached from its origin at the anterior superior spine and reflected inward subperiosteally with the adjacent portion of the iliacus muscle from the inner surface of the ilium

The incision is deepened to expose the hip joint, the iliacus being retracted inner edge pointing into the pelvis and driven directly through the superior lip of the acetabulum Then the tendon of the iliopsoas muscle is retracted inward and the osteotome is placed as close to this as possible and obliquely to the lip of the acetabulum and again driven through the margin of the acetabulum into the hip joint These two cuts join to detach this large section of the acetabular rim, which includes part of the anterior wall and of the roof of the acetabulum This heavy section of bone is

reflected outward, being still attached to the capsule of the hip joint The portion of the capsule of the joint to which it is attached is excised a triangular section being removed The movement of the hip is then layers using heavy silk or chromic catgut without drainage No immobilization is necessary The patient is placed in bed for two weeks, usually with the leg abducted and a pillow under the knee At the end of this

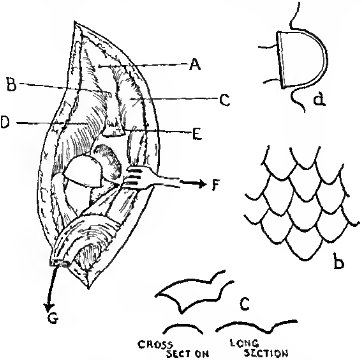


FIG 395 Smith Petersen cup arthroplasty Preliminary steps are similar except for special instruments to fascial arthroplasty (Fig 394) (A) Denuded iliac crest (b) denuded anterior superior spine—these are bared by (C) subperiosteal reflection of iliacus and (D) subperiosteal reflection of gluteus tensor and sartorius (E) cut attachment of rectus (F) retraction of iliacus and adductors (G) reflection of cut rectus Head is shown with cup applied ready to be slipped into reamed out acetabulum As much capsule as possible has been resected Insert (a) shows relative sizes of head cup and acetabulum Cup must move freely on head and in acetabulum Insert (b) shows design of serrations on Smith Petersen reamer allowing clearance for bone dust Insert (c) shows design of special chisels used by Smith Petersen to form head and acetabulum Double curve approximates desired surface contours

tested and if flexion and internal rotation are still restricted more of the superior or anterior portion of the margin of the acetabulum is removed

No attempt is made to close the capsule of the hip The tendon of the rectus femoris is sutured and the wound is closed in time the sutures are removed and the patient is gotten up on crutches and begins to exercise the limb

Other than exercise no after treatment is necessary

Arthroplasty of Hip (Campbell) (Fig 394) The joint is exposed through the an

terolateral incision of Smith Petersen (See p 458)

If the line of fusion between the head of the femur and the acetabulum can be identified, this is used as a line of cleavage If this cannot be identified the line of cleavage is chosen one fourth of an inch above what is believed to be the margin of the acetabulum, and a large Murphy gouge or a large woodcarver's gouge is driven directly into the side of the ilium at right angles to the surface of the bone for a distance of one and one half inches The gouge is then brought forward and driven into the bone and pushed backward and driven into the bone to separate the head of the femur from the ilium By adduction and external rotation and prying with a large woodcarver's gouge, the head of the femur is separated from ilium and hip is dislocated by forcible adduction and external rotation

As the head of the femur is dislocated, any adhesions on its posterior surface may be cut with scissors or with a knife However, as little soft tissue as possible is stripped up from the neck of the femur in order to conserve its blood supply Any contracted soft tissue structures are cut or relaxed in order to provide motion, that is, if necessary, the sartorius is cut and also the adductors may be divided Then the head of the femur is delivered into the wound by strong adduction and external rotation of the hip The head is trimmed down with an osteotome until it is roughly its normal size It is then smoothed either with a Murphy female reamer or with a shoemaker's rasp Likewise, with a large woodcarver's gouge the acetabulum is reshaped and enlarged until it is fairly round and smooth It is then smoothed with a Murphy male reamer until it conforms to the head of the femur

The hip is now reduced From the lateral surface of the thigh on the same side a strip of fascia from six to eight inches in length, and approximately four inches in breadth, is removed through a long lateral incision This wound is closed, the hip is again dislocated, the joint is carefully wiped out, and any particles of loose bone in the wound are removed The strip of fascia with its rough surface against the bone is then laid over the neck of the femur and one end of the strip is sutured around the superior portion of the neck of the femur close to the head The strip is then reflected over the head and its middle portion is sutured to the posterior portion of the neck of the femur or to its adjacent soft tissues The free end of the strip is then brought forward and folded over the head, and the head of the femur is reduced into the acetabulum The free end of the strip, thus lining the acetabulum, is smoothed out as well as possible and sutured around the margin of the acetabulum either to the soft tissues or to the bone

The wound is then closed in layers, and the extremity is immobilized in a large single plaster-of paris spica in a position of moderate abduction Campbell places strips of adhesive on the leg and applies from 10 to 20 pounds of traction to the extremity in the spica, which has been applied over a thick cotton padding so that the traction may actively pull the leg down within the plaster This spica and the traction are left on for ten days, at the end of which time the plaster is bivalved from the ankle to the crest of the ilium to permit flexion of the hip By means of a sling and pulley attached to an overhead bar the patient begins to carry out passive and active exercises These movements are increased as tenderness subsides and active motion is begun as soon as possible

After from four to six weeks the spica is removed and the patient is permitted to walk with crutches, but be should lie in bed part of the time in the posterior portion of the cast in order to insure abduction of the hip and to prevent any tendency toward flexion deformity The crutches are continued for from three to four months or until the patient is able to get along

without them, the progress of the condition of the bone being followed by x ray The crutches are discarded when the bone becomes sufficiently dense to bear weight without support, or when the patient is able to get along without them

The exercises should continue for at least a year

Cup Arthroplasty (Smith Petersen) (Fig 395) The incision begins on the crest of the ilium about two inches behind the anterior superior spine, extends forward along the crest to the anterior spine and then downward and inward along the outer border of the sartorius muscle The incision along the crest is extended down to the bone and the tensor *fascia femoris* and the anterior portion of the gluteus medius muscles are stripped up The incision is then deepened down along the anterior border of the ilium to the anterior inferior spine The sartorius muscle and the adjacent portion of the iliacus muscle are separated from the anterior superior spine and the adjacent portion of the inner surface of the ilium and are reflected inward

The incision is then deepened to expose the upper portion of the rectus femoris muscle The origin of this muscle is detached from the anterior inferior spine and is turned downward and fastened with a suture in the lower portion of the wound The soft tissues over the capsule of the hip are removed by sharp dissection and the capsule is opened by a T incision to expose the junction of the head of the femur and the acetabulum A large woodcarver s gouge or a special gouge is then driven into the line between the head of the femur and the acetabulum being driven vertically inward for a distance of about one and one half inches The gouge is then removed and the separation between the head of the femur and the ilium is continued until the head has been loosened from its ankylosis By prying with the gouge and adduction and external rotation of the femur, the head is separated from the acetabulum and dislocated by strong adduction and external rotation of the limb

After the head of the femur has been delivered into the wound, it is smoothed with an osteotome or gouge and is then further smoothed with a female Murphy rasp or with a woodcarver s rasp With a curved gouge the acetabulum is then shaped to fit the head and with a male rasp its surfaces are smoothed Then a vitallium cup is fitted over the head of the femur, there being

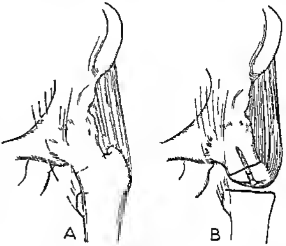


Fig 396 Jones pseudarthrosis for fixed hip (A) shows bone to be removed, leaving glutei attached to trochanter fragment, (B) shows trochanter fragment screwed on to stump of neck, interposing a muscular pad between shaft and neck Psoas iliacus acts on shaft

several sizes of cups available, and the head is reduced into the acetabulum The acetabulum should be sufficiently deep so that the head and the cup sink well into the socket The origin of the rectus muscle is then resutured to the soft tissues in the region of the anterior inferior spine and the wound is closed in layers The after treatment is the same as has been described in Campbell s procedure

Jones s Pseudarthrosis of Hip for Bony Ankylosis (Fig 396) A six inch longitudinal incision is made over the lateral surface of the thigh, the incision beginning

just above the greater trochanter and extending downward The incision is carried directly down the side of the femur, cutting through the deep fascia and the upper portion of the vastus lateralis muscle The trochanter of the femur is exposed and is cut across at the base with a broad chisel or osteotome, the gluteal muscles being left intact The severed trochanter is then reflected upward The tissues are stripped from either side of the upper portion of the femur and the shaft of the femur is divided transversely just above the lesser trochanter This division may be made with a Gigli saw or with an osteotome Then the neck of the femur is divided at right angles to its long axis, in order to separate the thickened portion of the bone which makes up base of the trochanter, base of the neck, and upper portion of the shaft

The trochanter is then brought downward and inward and is placed in contact with the stump of the neck of the femur, and is fastened with a stainless steel nail or screw The proximal portion of the shaft of the femur, including the lesser trochanter, is then displaced mesially under the stump of the neck and the attached trochanter thus interposing the attached muscles between the head and the shaft of the femur, to produce the pseudarthrosis The leg is immobilized for two weeks in a position of moderate abduction and flexion and in a neutral position as regards rotation, by a plaster-of paris spica which extends from the nipple line to the toes At the end of this time, the plaster is bivalved, and gentle movement is begun At the end of four weeks as muscle power begins to increase, the patient may begin to walk with a Thomas caliper brace and crutches continuing for at least six months

OPERATIONS ON KNEE

Synovectomy A skin incision begins about three or four inches above the patella in the midline It extends downward and inward to a point about one fourth of an inch opposite the upper border of the patella From this point it courses downward and slightly mesial to the margin of the patella to its lower pole where the incision turns outward toward the tibial tubercle and is carried down to this point [See Chapter 38 for incision illustration —Ed] The incision is carried directly down through the fascia to expose the capsule of the joint and the quadriceps tendon The quadriceps tendon is split just mesial to its midline, the incision is continued through the quadriceps bursa, and is carried inward around the patella, downward along the medial border of the patella, through the capsule of the joint, toward the tibial tubercle to expose the fat pad

After the quadriceps tendon and the capsule of the joint have been incised the synovial membrane is exposed in the depths of the wound This is stripped up from the lateral border of the capsule by blunt dissection to expose the lateral reflection on the side of the femur The dissection is carried upward in the quadriceps pouch and the synovial lining of this pouch is stripped from the underlying soft tissues and pulled downward on the femur The synovial membrane is excised usually close to the margin of the patella, and the patella is slipped outward over the external condyle to expose the lateral portion of the joint The synovial membrane which has been freed in the quadriceps region is then stripped from the lateral portion of the joint and from the sides of the femur by blunt dissection It is excised around the margins of the condyles and around the cartilage covering the patella The fat pad with its synovial surface is then removed Attention is next given to the lateral recesses of the joint, and as much of the synovial membrane as possible is removed from both the mesial and lateral recesses of the joint on the adjacent sides of the femur and tibia by sharp dissection The internal and external semilunar cartilages are then

examined If they are frayed or diseased, they are removed Attention is now given to the cartilage covering the femur and the patella Areas of fibrosed and diseased cartilage are excised by sharp dissection to leave a smooth surface As a rule, the underlying bone is not cut away Marginal exostoses on the femur and the patella are removed with an osteotome the surfaces of the joint are thus made smooth, and free of diseased cartilage, and are reduced in size The tourniquet, if one has been used is now removed and all vessels of importance are tied with fine silk The patella is now replaced Sufficient capsule should have been left along its border, so that the capsule and tendon can be sutured with medium silk The wound is closed in layers

After treatment The limb is immobilized in extension in circular plaster of paris for ten days or two weeks At the end of this time the plaster is removed, and active movement is begun It is increased as tolerated At the end of approximately three weeks the patient is gotten up on crutches, and begins to exercise the limb The crutches are continued until the patient can get along without them If fairly free motion is not present three weeks after the operation, the patient is anesthetized and the knee is gently flexed to 90° and then extended

Revision of Knee Joint The joint is opened by the median parapatellar incision just described The patella is then displaced outward, over the lateral condyle of the femur, to expose the articular surface By retraction, the margins of the condyles of the femur are exposed to inspection Large exostoses or osteophytes are excised with a chisel or osteotome, leaving the articular margin of the femur relatively smooth Areas of thickened, fibrillated or degenerated cartilage are excised with a knife Eburnated bone is not disturbed Any loose bodies in the joint or any areas of marked thickening of the synovial membrane are removed A total synovectomy is not attempted

The patella is then turned over and its inferior surface is inspected If it is markedly thickened, approximately half of its entire thickness is excised, and any overhanging margins on either side are removed with bone cutting forceps The articular surface of the patella is made smooth and a portion of the fat pad and of the adjacent tissue on either side is dissected up to form a covering for the raw surface if the patella has been reduced in thickness The semilunar cartilages are inspected, and, if they are frayed or diseased, both cartilages are removed A portion of the fat pad is excised if it is markedly thickened The patella is now replaced, and the capsule of the joint is closed with interrupted sutures of medium silk Subcutaneous tissues and skin are sutured with interrupted sutures of fine silk

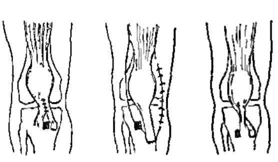
The limb is immobilized for two weeks in circular plaster of paris in full extension If a tourniquet has been used this is removed before the wound is closed and all bleeding vessels are tied Those inside the joint are tied with fine silk ligatures so that the joint is rendered as dry as possible before closure of the wound At the end of two weeks the plaster of paris is removed and the patient begins to exercise the knee In about another week he may begin to walk with crutches The crutches are gradually discarded as function returns If the knee is quite stiff three weeks after the operation it should be manipulated under general anesthesia

Excision of Patella When performed in a patient with hypertrophic arthritis or with arthritis which has developed from an old fracture of the patella, this bone may be most conveniently excised through a midline incision which begins above the superior border of the patella and extends directly downward over the patella and the patellar ligament It is

carried down through the fibers of the quadriceps tendon to the bone By sharp dissection the fibrous tissue on the anterior surface of the patella is dissected back on either side to expose the anterior surface of the bone The attachment of the quadriceps tendon above and on one side of the patella is shelled free from the bone, the dissection being continued around its margin, care being taken to preserve as much of the longitudinal structure of the capsule as

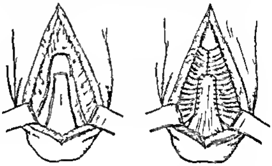
The limb is then immobilized in circular plaster of paris for a period of two weeks At the end of this time the plaster is removed, and the patient may begin to exercise the leg At the end of another week he may get around on crutches These are discarded as soon as sufficient power returns to permit him to go without them

Excision of Necrotic Cartilage The area of diseased cartilage is shaved evenly off with a knife until smooth healthy tissue



A B C

Fig 397



A B

Fig 398

Fig 397 Three methods of transplant for recurrent dislocation of patella A bony block is transplanted in each instance, and in one coincident overlap suture is performed on the medial aponeurotic expansion

Fig 398 Quadriceps lengthening by Bennett method (A) Line of incision of tendon followed by flexion of knee joint, with resultant separation of distal segment from proximal one (B) method of suture in flexion of separated tendon

possible until the lower pole is reached Then the attachment of the patellar ligament is separated close to the bone by sharp dissection, and the section is continued upward on the other side, separating the margin of the patella from the capsule of the joint and from the quadriceps tendon

The interior of the joint is then inspected and any pathologic changes which seem to warrant correction are attended to Large osteophytes on the margins of the femur are excised, as described under revision of the knee joint The semilunar cartilages, if markedly diseased, are removed The margins of the aponeurosis which have covered the anterior surface of the patella are sutured with interrupted sutures of fine silk Fine silk is also used for the subcutaneous tissues The skin is closed with silk sutures

is exposed. The wound is closed in layers with fine silk for the synovial membrane, medium silk for the capsule, and fine silk for the subcutaneous tissues The limb is immobilized in a pillow splint or in a large pressure bandage for about four days At the end of this time the bandage is removed and replaced with an elastic bandage The patient may then begin to exercise the limb The amount of motion is increased gradually, weight bearing is begun in a few days

Operation for Slipping Patella (Fig 397) There are numerous operations for this condition The one which I prefer is that of Hitchcock It consists of transplantation downward and inward into the tibia of a portion of the patellar ligament with its attached bone

Technic The incision begins on the

mesial side of the patellar ligament and extends downward and inward to approach the mesial border of the tibia about three inches below the joint This is carried down through the fascia to expose the patellar ligament The lateral margin of the wound is retracted to expose the tibial tubercle and the patellar ligament The patellar ligament is split longitudinally down to the tibial tubercle With a thin osteotome the mesial half of the tibial tubercle is excised as a square block of bone approximately three quarters of an inch in width and approximately one inch long and about one third to one half of an inch thick This block is lifted out of its bed with the attached half of the patellar ligament It is pulled downward and inward toward the mesial border of the tibia as far as it will go with a moderate amount of tension At this point an outline of a block of bone is made on the anteromesial surface of the tibia and with a thin sharp osteotome The cortex of the tibia is removed the block being approximately the same size or slightly smaller than the block of bone removed from the tibial tubercle The latter is then hammered into the defect so created fitting sufficiently tight so that it is stable This results in relaxation of the remaining half of the patellar *tendon* which is still attached to the tibial tubercle This is then pulled to the inner side and sutured with medium silk sutures to the margin of the transplanted *inner half of the tendon closing the gap* between the two portions of the tendon The subcutaneous tissues are then closed with interrupted sutures of fine silk and the skin is closed with a *continuous* silk suture A plaster of paris circular plaster is applied with the limb in full extension The plaster is well padded It is not a walking cast It is left on for from three to four weeks At the end of this time the plaster is removed and the patient begins to exercise the knee He may begin weight bearing as soon as the knee feels sufficiently stable Movement is gradually increased and crutches are discarded as soon as the patient finds that he is able to do without them satisfactorily

Lengthening of Quadriceps Tendon (Bennett) (Fig 398) A straight longitudinal incision begins at the junction of the middle and lower thirds of the thigh in the midline on the anterior surface and extends directly downward to a point over the middle of the patella This incision is carried down through fascia to expose the quadriceps tendon The soft tissues are retracted to either side and the quadriceps tendon is exposed by blunt dissection This tendon is then outlined and severed on either side from its attachment to the vasti at its superior portion and is cut across by the V method the apex of the V pointing upward The lateral incision on each side extends entirely through the tendon severing it from the muscle on either side down to the upper margin of the patella The quadriceps tendon can now be lifted out of the wound

It is usually stated that the knee can now be flexed without resistance As a matter of fact however the strongest adhesions are usually found to consist of thickening of the joint capsule laterally on either side from the superior pole of the patella binding this bone to the condyles of the femur Consequently the incision must be carried down around the superior portion of the patella on either side and then laterally across the aponeuroses If there are any intra articular adhesions these should be severed The knee is then flexed to approximately an angle of 90° *This* movement pulls the *tongue* of the quadriceps tendon downward for a variable distance usually about two inches

With the knee flexed the vastus lateralis and medialis *muscles are now joined above* the tendon with interrupted sutures of silk The margins of these muscles are then sutured to the margins of the tendon on either side, thus reconstructing the quadriceps extensor apparatus above the patella However it will be found that when the knee is flexed there is a gap of approximately one and one half to two inches on either side of the superior pole of the patella where the incision was carried laterally across the ex

pansions This cannot be closed entirely and there is therefore a dead space with the knee flexed I partially close it by splitting the adjacent portions of the vastus lateralis and medialis muscles and swinging a loose flap of muscle tissue across to cover the opening in the joint cavity and to separate it from the deep fascia The skin and fascia are then sutured with interrupted medium silk The limb is immobilized in a position of approximately 90° flexion if this can be obtained without too great tension or less flexion if necessary in plaster of paris for two weeks At the end of this time the plaster is removed and active movement is begun and gradually increased The patient may be up on crutches in three or four weeks after the operation These are discarded as soon as the patient is able to get along without them

Popliteal Dissection or Posterior Capsulotomy With the patient lying on his face an incision approximately eight inches in length is made in the midline posteriorly The level of the knee joint lies approximately at the junction of the middle and lower thirds of this incision It extends down to the deep fascia The superficial fascia is dissected back on either side and retracted to expose the tendon of the biceps and the peroneal nerve laterally and the inner hamstrings mesially The deep fascia is then cut transversely including laterally the taut iliotibial band The tendon of the biceps is lengthened by the Z method The peroneal nerve which lies on the deeper aspect of the biceps tendon is freed from the tendon and is retracted In the mesial part of the popliteal space the prominent inner hamstrings are also lengthened by the Z method It is not necessary to repair these tendons by careful suture They are merely split longitudinally for about three inches and the two sides sectioned at different levels The ends are slid by and sutured with medium silk

The incision is then deepened in the midline, or slightly lateral to the midline between the peroneal and the tibial nerves, through the deep fat to the region of the posterior capsule of the knee joint and the posterior surface of the lower end of femur The popliteal artery and vein lie superficial to these structures and are retracted to the inner side with the posterior tibial nerve and are not exposed in the wound The short branches from these vessels which pass through the posterior portion of the joint are ligated

The mass of fat is pushed to either side using a gauze sponge on the operating finger to expose the posterior capsule of the knee joint and the origins of the gastrocnemius muscle A transverse incision is made across the posterior capsule of the knee joint cutting the tendons of origin of the popliteus and of the gastrocnemius muscles. The knee is then gently straightened and the posterior crucial ligament is cut under direct vision Care is taken not to straighten the knee too forcibly Otherwise the posterior tibial or popliteal vessels and nerves may be injured The tendons having been sutured as they were divided, the wound is now closed by suturing the superficial and deep fasciae longitudinally with fine silk with continuous suture for the skin The limb is immobilized in plaster of paris in a position of moderate extension for a period of from ten days to two weeks At the end of this time, further straightening of the limb is begun either by a wedging plaster or by traction As a rule I use the wedging plaster as it is less troublesome and more comfortable to the patient It has the disadvantage however that more time is required later in restoring movement to the knee and power to the quadriceps muscles which have been stretched by the contracture

Wilson's Method An incision about five inches long is made over the lateral aspect of the knee extending from above the condyles of the femur to the head of the fibula The iliotibial band is divided transversely two inches proximal to the joint The biceps tendon is isolated for a distance of four inches from its insertion, and the peroneal

nerve is separated from its inner and deep surfaces The tendon is split and lengthened by the Z-plastic method The incision is now carried down to the lateral condyle of the femur in its posterior portion, and the capsule of the knee joint is incised at the posterior margin of the condyle With a periosteal elevator the capsule is stripped upward from the posterior aspect of the femur for about three inches above the joint the outer head of the gastrocnemius muscle being cut across The stripping is continued toward the inner side of the femur

A second incision is now made on the inner aspect of the lower thigh from a point just above the adductor tubercle to below the joint line This incision is carried through the deep fascia to expose the posteromesial aspect of the joint capsule The capsule is incised along the posterior margin of the condyle of the femur through periosteum The mesial head of the gastrocnemius is severed from its attachment to the femur The capsule of the knee is stripped from the femur by blunt or sharp dissection with the periosteum

The knee is now gently straightened If motion is found to be restricted by the structures in the intercondylar notch, a piece of gauze is passed across the knee in the popliteal space and the soft tissues are retracted from the bone to expose the posterior portion of the joint The posterior crucial ligament and any other structures limiting extension of the knee are divided by sharp dissection The knee is now gently extended, the peroneal nerve being closely watched If this is unduly taut, it is freed down to and around the head of the fibula With as much extension as can be obtained without undue tension, the divided ends of the biceps femoris muscle are now sutured together The wounds are closed in layers, using medium silk for the deep fascia and fine silk for the subcutaneous tissues and continuous sutures for the skin The knee is now immobilized in plaster of paris in moderate extension, care being taken to avoid undue tension At the end of two weeks further extension may be gained either by traction in Buck's extension or by means of a wedging plaster In some instances, a long brace which maintains extension while walking, but permits flexion while sitting, is worn In most instances a night splint, or a bivalved plaster mold at night, is worn for several months in order to prevent recurrence of the deformity This is not applied, however, until the maximum amount of extension is obtained, either by traction or by means of a wedging plaster

Supracondylar Osteotomy of Femur for Flexion Contracture A straight incision on the lateral side of the knee just anterior to the iliotibial band is carried down to the bone The deep fascia is split longitudinally, and the iliotibial band is divided transversely The tissues on the lateral side of the thigh are retracted to expose the tendon of the biceps femoris muscle The lower four inches of this muscle and tendon are exposed and freed from the peroneal nerve which lies close to the posteromesial aspect of the muscle The tendon is then split and lengthened by the Z method The lateral surface of the femur just above the condyles is exposed, the periosteum is split longitudinally and stripped to expose the entire lateral and posterior surface A drill one-fourth of an inch in diameter is then passed directly through the bone at a point opposite the adductor tubercle and about one third of the distance between the anterior and posterior surface of the bone—that is, closer to the anterior aspect This drill, after it passes through the bone, can be palpated in the mesial aspect of the thigh It is left in situ and a short incision about four inches long is made on the mesial aspect of the thigh with its center just below the drill point This is carried down through the muscles and periosteum to expose the mesial aspect of the femur

A smaller drill, approximately one-eighth to three sixteenths of an inch in diameter, is passed directly through the femur near its posterior surface, approximately one inch distal to the preceding drill If de-

sired, one or more drill holes of similar diameter may be made in the line connecting this with the first drill hole A third small drill is passed directly through the femur from side to side as close as possible to its anterior cortex and approximately one half an inch distal to the first drill With a thin, sharp osteotome these drill holes are then connected on either side and the incision is carried directly across the anterior and posterior surfaces of the femur There is thus formed a V shaped osteotomy of the femur with the opening of the V upward The flexed knee is then gently straightened without undue tension and the subcutaneous tissues and skin are closed with silk A plaster of paris spica is then applied with the knee in as much extension as can be obtained without undue tension, care being taken to watch the circulation of the foot The plaster is well padded over the front of the knee and over the heel At the end of from ten days to two weeks the plaster can be cut across posteriorly at the knee, the anterior portion being left attached as a hinge, and the knee can be gently wedged until as much straightening as is desired is obtained If the surgeon prefers a curved osteotomy of the femur may be performed, either by means of multiple drill holes which are joined by cutting the intervening bone with a thin osteotome or it may be made by means of a narrow saw or a curved osteotome Postoperative x rays are used to control the position of the fragments If the position is not satisfactory, it is corrected by wedging the plaster The plaster is left on for approximately ten weeks At the end of this time it is removed, and the patient may begin to exercise the leg without weight bearing At the end of two weeks the patient is gotten out of bed, and weight bearing is begun with crutches Crutches are continued until the limb is strong enough to do without them

Supracondylar Osteotomy for Lateral Deviation (Genu Varum or Genu Valgum) The femur is exposed from the lateral aspect, from the mesial aspect, or from both In the case of an adult the control of the fragments, and the correction of the deformity after the bone is cut, may be a rather difficult procedure It is usually advisable to obtain the correction by the removal of a suitable wedge The size of the wedge can be determined by tracing the bones of the limb in an anteroposterior x ray, and then cutting the tracing across at the point of the proposed osteotomy On straightening the tracing the amount of overlap will determine the size of wedge to be removed in order to correct the deformity

The wedge should be removed from the lateral side to correct genu varum (bow legs) The incision is made on the lateral side of the lower thigh and extends directly downward The iliotibial band is split and the incision is carried down to the femur, splitting the lower portion of the vastus lateralis muscle in line with its fibers The periosteum is split longitudinally, and is stripped up on either side for a distance of about three inches The osteotomy is performed through the cancellous bone just above the condyles where the bone is fairly wide—that is, at approximately the level of the adductor tubercle

The amount of bone to be removed in the wedge having been calculated, a thin osteotome is driven through the cortex, and the second cut is made above or below this to outline the wedge The two cuts are carried directly through the bone, removing a wedge of approximately the size determined by the measurement Small, thin osteotomes are used and the cortex is followed around When the inner cortex is almost completely divided the remaining portion of the bone is broken by forcibly bending the leg in a direction away from the wedge, that is, if the lateral wedge is being removed for the correction of bowlegs, the bowleg deformity is increased in order to break the bone Then the leg is bent outward to correct the deformity by bringing the two margins of the wedge together In the case of an adult it is well to bore small holes through each

fragment and fix the two edges together with loops of stainless steel wire This will not be sufficient to maintain the correction of the deformity, but will prevent upward or downward displacement of fragments

The limb is immobilized in a plaster-of-paris spica which gets a firm grip on the pelvis and extends to the toes The extremity is in a position of slight overcorrection The plaster is left on for a period of from eight to 12 weeks The postoperative position is checked by x ray If it is found to be unsatisfactory it is corrected by wedging the plaster When union is judged to be sufficiently firm, the plaster is removed and the patient may begin to exercise the limb in bed About two weeks after removal of the plaster the patient may be gotten up on crutches, and may begin to bear some weight on the leg The crutches are discarded as soon as the bone is strong enough

In similar operations in children it is usually satisfactory simply to cut the bone across and to correct the deformity by bending the leg inward or outward as the case may be, thus opening a defect on the concave side of the deformity In children this defect is rapidly filled with bone If the surgeon desires, the defect may be partially filled with bone chips removed from the adjacent portion of the cortex

Osteotomy of Tibia and Fibula for Correction of Lateral Deviation In instances in which the knock knee or bowleg deformity is principally in the tibia and fibula, it is advisable to perform the operation below the knee

If the deformity is a knock knee deformity, a relatively large wedge is removed from the tibia, this wedge having a wide base in order that the bone may be shortened sufficiently to correct the deformity Through an incision about four inches long on the inner aspect of the leg at a point opposite the tibial tubercle, the tibia is cut across with an osteotome, two sections being made at approximately the distance apart to permit correction of the deformity As a rule it is not necessary to perform an osteotomy of the fibula However, if, after removal of the wedge from the tibia, the deformity cannot be readily corrected, an incision about two inches long is made over the head and neck of the fibula The peroneal nerve is identified and retracted posteriorly Then the fibula is cut obliquely from without inward and downward, thus avoiding injury to the nerve and avoiding placing excess callus or rough bone beneath the point where the nerve curves around the neck of the fibula

For the correction of a bowleg deformity, a simple transverse section of the tibia is made through an incision about four inches long on the anteromesial aspect of the leg Care in driving the osteotome through the outer cortex of the tibia should be taken, not to injure the anterior tibial artery In cutting the posterior cortex of the tibia the periosteum is stripped up and the tissues are held away from the bone and protected with a spatula or other instrument while the cortex is cut with a thin, narrow osteotome The upper portion of the fibula is then exposed through a lateral incision approximately two inches long which begins just above the head of the bone and extends directly downward This incision is carried through the deep fascia The peroneal nerve is identified and retracted posteriorly Either with an osteotome or with heavy bone cutting forceps a small transverse section is removed from the fibula after the periosteum has been split longitudinally and stripped up from the bone This section permits shortening of the fibula and as the leg is bent outward to correct the deformity the two ends of the bone come together, or the fibula may be cut obliquely and the ends overlapped

The wound is closed in layers with interrupted sutures of fine silk and the skin is closed with continuous silk sutures If jagged bone is in juxtaposition to the peroneal nerve a small bit of fat or of soft tissue in the vicinity is placed under the nerve between it and the bone The deformity is slightly overcorrected in either

the varus or valgus direction and plaster of paris is applied which extends from the groin to the toes The position is checked postoperatively by x ray If it is found to be unsatisfactory, the deformity is corrected by wedging the plaster The plaster should remain on for eight weeks At the end of this time it can be removed and the patient may begin to exercise the leg He may be gotten up on crutches about two weeks after removal of the plaster The crutches are continued until the leg is strong enough to bear weight without them

Arthrodesis of Knee [See also Chapters 7 and 14] The operation is usually performed under a tourniquet A U incision is used It begins over the mesial condyle of the femur at approximately the middle of the patella or at its upper border It is curved downward and outward to cross the patellar ligament at approximately the joint line, and then curves outward and upward to a point opposite its origin It is carried directly through the deep fascia and joint capsule the patellar ligament being cut across in the line of the incision The patellar ligament and capsule are then reflected upward extrasynovially, and the synovia is separated by sharp dissection up to the margin of the patella It is then cut through around the lower margin of the patella and the patella is reflected upward The dissection of the synovia is continued around the margin of the patella until its upper portion is free It is then pulled downward and dissected free from the femur, being cut loose around the margins of the articular surface and as far down as possible on either side of the joint beneath the external and internal lateral ligaments The entire synovial membrane and fat pad are thus removed from the front and sides of the joint

The knee is then flexed and with a hand saw the lower end of the femoral condyles is cut squarely across, the cut corresponding with the angle at which an arthrodesis is desired that is, square across for arthrodesis with a straight knee or inclined slightly backward and upward for arthrodesis with slight flexion Since it is not possible to continue the saw cut to the posterior margin of the condyle, it is continued as far back as possible, and then finished with a thin osteotome, the rounded ends of the condyles being removed With an osteotome the cartilage is then removed from the front and from the posterior portion of the condyles of the femur The semilunar cartilages are removed by sharp dissection and the crucial ligaments are cut across

With a saw, a thin section of the upper end of the tibia is removed as far back as possible, and is then finished with a thin osteotome to remove the articular surface of the tibia The synovial membrane lining the posterior capsule of the joint is then removed by sharp dissection The ends of the bone are fitted carefully together It is desirable that they fit neatly, and that, when they are approximated, the leg be in the desired position, that is either straight or slightly flexed The cartilage is then removed from the deep surface of the patella, either with a saw or with an osteotome

Through a straight longitudinal incision a broad bone peg is then cut with a motor saw from the anteromesial surface of the tibia of the same leg This peg should be approximately five inches long, and is bluntly pointed at either end It should be approximately a half an inch wide After it is removed, the margin of the slot from which the peg was removed should be notched by cutting up slivers of bone from the margin, which curve inward to fill in the defect A rather thick osteotome approximately one inch wide is then driven directly upward in the center of the end of the femur for a distance of approximately two inches The thick pointed bone peg is then driven into the hole A similar osteotome is driven downward through the upper surface of the tibia The leg is then manipulated so that the point of the bone graft which is projecting from the end of the femur is inserted into the hole in the upper end of the tibia. By pushing the ends of the bones together, the central autogenous graft tends to hold

the ends of the bone in place The wound is now closed with interrupted sutures, using heavy silk for the capsule and fine silk for the subcutaneous tissues and a continuous silk suture for the skin

The limb is immobilized in a plaster of paris spica, which must be left on for at least two months At the end of this time the plaster is removed The stability of the limb is tested If it is not found sufficiently stable, a skin tight circular plaster is applied The patient may begin to bear weight in this plaster if the arthrodesis has not been performed for tuberculosis In certain instances where a plaster-of paris spica is not desirable, adequate fixation can be obtained by passing a Kirschner wire through the femur at the junction of its middle and lower thirds This wire is drilled through the bone after the arthrodesing operation has been completed It is allowed to project on either side, and a circular plaster is applied over it with the limb held in the desired position After the plaster has set, a Kirschner bow is applied to hold the wire taut This will firmly fix the plaster to the femur, and will give sufficient immobilization to secure union without the necessity of a spica to include the hip In other instances where positive pressure is desired, a second wire is passed through the upper third of the tibia and the two are pulled together, and incorporated in the plaster cast

Method of R N Hatt Hatt has used a method similar to the above except that instead of driving the peg into the femur and then impaling the tibia upon it he cuts his bone peg from the upper portion of the crest of the tibia and drives the peg directly through the upper end of the tibia from below upward into the femur I have not used this method, but believe that it may have certain advantages over the method described above Hatt has also shown by extensive clinical experience, that the autogenous bone peg may be driven through the epiphyses in children with relative safety and will not interfere with growth Prior to the publication of Hatt s paper, I had used the method only in adults

Arthroplasty of Knee (Campbell) (Fig 399) The incision begins over the mesial border of the quadriceps tendon about six inches above the knee It is carried vertically downward, and then inward around the median margin of the patella then downward and outward to a point opposite the tibial tubercle The quadriceps tendon is then split in its lower portion near the median border to just above the patella This incision through the tendon and capsule is curved inward around the patella to a point opposite the tibial tubercle, and is carried through the synovial membrane down to bone

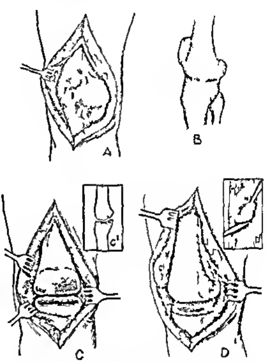


Fig 399 Knee arthroplasty (after Campbell) (A) Separation of patella (B) bone to be excised to produce single rounded condyle (C) completed excision (C lateral view) (D) femur and tibia covered by fascial sheet, patella covered by fatty tissue reflected from below (D)

The union between the patella and the femur is then divided with a chisel and

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Arthroplasty of Knee (Campbell) (Fig 399) The incision begins over the mesial border of the *quadriceps tendon* about six inches above *the knee It is* carried vertically downward, and then inward around the median margin of the patella, then downward *and outward* to a point op

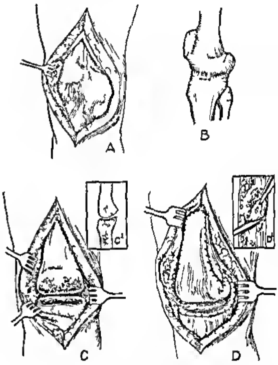


FIG 399 Knee arthroplasty (after Campbell) (A) Separation of patella (*B*) bone to be excised to produce single rounded condyle (C) completed excision (C' lateral view) (D) femur and tibia covered by fascial sheet patella covered by fatty tissue reflected from below (D')

posite the tibial tubercle The quadriceps tendon is then split in its lower portion near the median border to just above the patella This incision through the tendon and capsule is curved inward around the patella to a point opposite the tibial tubercle, and is carried through the synovial membrane down to bone

The union between the patella and the femur is then divided with a chisel and

the patella is reflected outward, freeing any adhesions between the soft tissues on the lateral side of the joint and the bone These tissues are removed by sharp dissection so that a free exposure of the anterior portion of the femur and of the bony union between the femur and the tibia is obtained Then, with a thin, broad osteotome the femur is divided from the tibia, care being taken not to injure the tissues posterior to the joint in the popliteal space The knee is gradually flexed and the posterior portions of the condyle of the femur are removed, obliterating the intercondylar notch and permitting full flexion The lower extremity of the femur is then rounded from above downward and before backward forming one large condyle with a square horizontal end and a relatively narrow edge Only enough bone is removed to reach cancellous bone between the condyles, the larger portion of the bone being removed from the posterior surface

The upper extremity of the tibia is now cut square across With a woodcarver's chisel or a wide gouge this surface is made slightly concave from before backward, forming a large shallow cavity for the articulation with the single condyle of the femur After excision of bone, manual traction on the tibia should produce a space approximately one half of an inch wide between the ends of the tibia and the femur No attempt is made to reproduce the spine of the tibia or the intercondylar notch of the femur The median and lateral ligaments are protected from injury during the procedure, and as little separation of the soft tissues from the bone is done as possible, so as not to interfere with the blood supply to the bone The bony surfaces are then approximated and the alignment of the extremity is observed If varus or valgus is present, additional bone is removed from the surface of the femur, until a perfectly square end is formed Valgus is to be especially avoided

A good portion of the patella is now removed, leaving only a thin layer of the anterior portion of the bone The lateral margins of the patella are trimmed for one-fourth of an inch to allow the fibers along the edges to pull backward on the posterior surface All osseous surfaces are smoothed with a wood file or rasp, and every particle of loose bone is removed from the joint The mass of fat just below the patella on the posterior aspect of the patellar tendon is used to fold over the patella which has been greatly reduced in size This is cut from below upward to form a pedicle flap which is stitched to the fatty tissue at the superior margin of the patella, the synovial and capsular tissue on either edge being drawn forward so that raw bone is covered with soft tissue

A long incision is now made on the outer side of the opposite thigh to permit the removal of a piece of fascia lata from eight to ten inches long and from four to five inches wide It is important that the skin incision be made only through the skin, otherwise a cut in the deep fascia may be made at a point which is to be the central portion of the free transplant This transplant is removed by sharp dissection and is folded with its smooth surface—that is, its deep surface—inward It is applied to the raw surface of the bone so that the outer (rough) surface of the graft is in contact with the raw bone One end of the transplant is anchored to the anterior border of the tibia It is then folded back into the joint and anchored to the posterior border of the tibia or to the tissues just behind it It is then carried up behind the posterior border of the femur in the posterior part of the joint and anchored in this area, and then its free end is brought forward and folded over the inferior and anterior surfaces of the femur The margins of the fascial transplant are sutured with No 0 chromic catgut to hold it in position, thus forming a double lining for the joint covering all of the bone surfaces, except that of the patella which has been covered with the fat transplant from below

With the limb straight, the wound is then closed in layers and a plaster-of paris spica

is applied extending from the toes to the lower ribs or the extremity may be immobilized in a Thomas splint in moderate traction No movement is permitted in the joint until the wound has entirely healed Active tensing of the quadriceps muscle however is encouraged after the first week At the end of about two weeks movement is begun If the limb has been immobilized in plaster of paris this is removed and the limb is suspended in a Thomas splint which will permit movement of the knee If the limb has been treated by traction this may be released at intervals during the day and the patient may begin to move the knee with a sling and pulley to pull up the knee It is important not to force movement in the early period after an arthroplasty In a lower extremity stability is a good deal more important than is movement and my poor results have been those with excessive movement but with insufficient stability Consequently I increase movement very slowly over a period of months I never expect to get more than 70 to 80° movement and believe that this gives a more satisfactory end result than does a knee with more motion and less stability

Excision of Baker s Cyst of Knee With the patient in the prone position an incision approximately six inches long is made in the midline of the popliteal space or slightly to the median side of the midline with the center of the incision directly over the most prominent portion of the cyst It is carried down through the deep fascia care being taken not to cut the lateral cutaneous nerve which lies on the outer side of the incision After the deep fascia is incised the dome of the cyst can be exposed by blunt dissection It is dissected free from the fat on either side care being taken to avoid rupturing it If it is ruptured the site of the rupture is clamped shut in order that the entire cyst may be removed It will be found that the cyst originates either in the neighborhood of one of the tendons of origin of the gastrocnemius muscle on the outer or inner side of the knee (sometimes in a bursa between the inner head and the semimembranosus tendon), or it may originate from the posterior part of the knee joint In either instance the pedicle of the cyst is ligated and an attempt is made to remove its entire wall In some instances the wall is very thin and rupture is unavoidable The wound is closed in layers and a pressure bandage is applied for a few days No special after treatment is necessary

Excision of Internal Semilunar Cartilage If the diagnosis is certain the internal semilunar cartilage is best excised by a small oblique incision or by the J shaped incision of Jones I prefer the incision which slopes from above outward and downward toward the tibial tubercle A large sandbag is placed under the knee and the table is broken so that the leg hangs over the edge of the table The patient is so draped that the leg can be manipulated freely The sandbag tends to push the tibia forward on the lower end of the femur The incision is begun over the internal condyle of the femur about one and one half inches mesial to the lower end of the patella It is inclined downward and inward to cross the joint at approximately the lateral border of the patellar fat pad and is carried to a point about one half of an inch below the joint line Care is taken to avoid injuring the infrapatellar branch of the saphenous nerve This nerve is large enough so that it may be possible to identify it in the superficial tissues If it is cut it may result in a painful neuroma later or it may result in anesthesia in the region of the tibial tubercle which persists for several months The nerve tends to lie along the lower border of the joint line and is parallel with the upper border of tibia

The incision is carried through the deep fascia and the synovial membrane to open the joint opposite the lower end of the inner condyle of the femur The lateral border of the fat pad is then cut across to expose the internal semilunar cartilage It is not possible through this incision to inspect the posterior portion of the cartilage However,

regardless of the operative findings, the cartilage is removed as nearly completely as possible The anterior portion of the cartilage is freed by sharp dissection from the upper end of the tibia Then by sharp dissection the cartilage is cut away from the capsule of the knee joint across the front of the tibia and around the lateral side as far back as possible A rather narrow retractor, approximately two inches long, is then placed in the joint between the cartilage and the internal lateral ligament and the cartilage is further dissected, using a knife curved on the flat if one is available The dissection is carried well back on the lateral side beyond the internal lateral ligament The cartilage is then grasped firmly with a pair of heavy toothed forceps and pulled outward so that it is snapped across the joint by tearing the posterior portion until it is delivered between the condyles of the femur The patellar fat pad is then retracted to the outer side, and the cartilage is dissected free from its posterior attachment and removed [For further discussion of the use of this incision, see Chapter 38 —Ed]

The operation is usually done without the application of a tourniquet and the vessels which are cut during the exposure are tied with fine silk The wound is closed in layers and a pressure bandage or pillow splint is applied for about four days At the end of this time the patient may begin to move the leg and may be up on crutches or preferably a cane as soon as he is able to do so and the crutches are discarded for a cane as soon as the patient is able to get along without them After the sutures are removed —that is, in about eight days—the patient is given exercises to strengthen the quadriceps muscles and these are continued until there is no need of further improvement

Excision of External Semilunar Cartilage The operation is carried out in the same manner as described above, except that the incision begins over the lateral condyle of the femur and is carried downward and inward toward the tibial tubercle The after treatment is the same

In instances where it is advisable to remove both cartilages, this may be done through the two anterior incisions as described above, or it may be done through the large median patellar incision such as that used for synovectomy and other extensive operations upon the knee or in extensive exploration of the anterior portion of the joint

Operation for Removal of Cyst of External Cartilage As a rule, cysts of the external cartilage occur quite far back on the lateral side of the joint so that a portion of the cyst may lie posterior to the external lateral ligament The cartilage may be considerably thickened and enlarged as a result of the cystic degeneration Considerable difficulty is encountered in removing the entire cartilage with the cyst through the anterior incision A lateral incision is carried down through the skin and subcutaneous tissues and the anterior margin of the wound is retracted forward A vertical incision anterior to the external lateral ligament is made through the capsule of the joint and by sharp dissection the external semilunar cartilage in its anterior portion is dissected free from its anterior attachment to the tibia and to the capsule This dissection is then continued backward along the margin of the cartilage until it is freed to a point posterior to the external lateral ligament

A second vertical incision is now made in the capsule posterior to the lateral ligament and the posterior portion of the cartilage is freed behind the lateral ligament and around the posterior margin of the upper end of the tibia At this point the anterior end of the cartilage is pulled posteriorly under the ligament and delivered in the posterior wound Then, while traction is made on the cartilage, its posterior attachment is cut from the tibia and the cartilage is removed The wound is closed in layers and treated as described above in excision of the semilunar cartilage

In rare instances of a cyst of the internal semilunar cartilage the operation is per

formed in the same manner on the inner side of the knee

Repair of Internal Lateral Ligament of Knee Occasionally an arthritis is the result of an old injury with a relaxed internal lateral ligament This is best repaired by means of re inforcing the existing internal lateral ligament with fascia [See Chapter 38]

Operation for Repair of External Lateral Ligament In rare instances where there is relaxation of the external lateral ligament, a similar operation may be per formed However, in this instance it is not necessary to drill a hole in the upper end of the tibia A lateral incision is made along the lateral side of the knee joint and a strip of fascia is lifted from the iliotibial band approximately one inch wide This is then divided into two strips, each approximately one half of an inch wide A tunnel is then made in the lateral condyle of the femur at approximately the point of attachment of the external lateral ligament This tunnel is made by making two drill holes through the cortex of the bone at an angle of about 45° so that they approach one another in the subcortical bone This tunnel is enlarged with a curette and the strips of fascia are pulled through, usually with a loop of stainless steel wire one in each direction so that they overlap and are pulled taut and they are then sutured outside of the bone with interrupted sutures of medium or heavy silk The wound is then closed in layers, and the leg is immobilized in a plaster of paris cylinder cast for a period of four weeks At the end of this time the plaster is removed and the patient may begin to bear weight upon the leg two weeks after the removal of the plaster, but is provided with a shoe with the outer border of the heel elevated a quarter of an inch in an effort to relieve the external lateral ligament from strain

Mauck Operation for Internal Lateral Ligament Relaxation. [See Chapter 38]

Repair of Anterior Crucial Ligament [See Chapter 38]

OPERATIONS ON ANKLE

Lengthening of Tendo Achillis (Fig 400) With the patient lying on his face a slightly curved incision is made along the mesial border of the tendo achillis, its length depending upon the amount of lengthening which it is desired to obtain This incision is curved from before backward so that when the posterior portion of the leg is lengthened the incision will be straight The incision is carried down to the tendon, its lower end approximating the posterior portion of the os calcis The peritendinous structures around the tendo achillis are divided and the plantaris tendon cut across and permitted to retract

The tendo achillis is then freed by blunt dissection, and split longitudinally in ap proximately its midline The longitudinal splitting may be in either the frontal or the sagittal plane The distance through which it is split depends upon the amount of lengthening desired If three inches of lengthening is desirable, the split is four inches long A cut is then made transversely at either end of the split in opposite directions, thus forming two half tendons which are permitted to slip by one another The foot is now dorsiflexed for the desired dis tance and when as much dorsiflexion as is desired is obtained the two limbs of the tendon are sutured together either with medium silk or with No 0 chromic catgut The peritendinous structures are sutured around the tendon with fine silk, the subcutaneous tissues with fine silk and the skin is closed with a continued suture of silk Circular plaster of paris is applied with the foot in the fully corrected position

If, after the tendo achillis has been divided, it is found that it is not possible to obtain as much dorsiflexion as is desired, the dissection is carried down through the posterior fat tissues between the tendon and the ankle joint, the fascia being divided to expose the posterior capsule of the ankle joint The posterior tibial vessels and nerves are retracted inward and the

posterior capsule of the ankle joint is divided throughout its width This will usually permit full correction of the equinus deformity The plaster is left on for four weeks At the end of this time it is removed and exercises may be begun, especially in dorsiflexion The patient may be permitted to be up and may begin to bear weight on the leg Full use is not permitted until about eight weeks after the operation

Osteotomy of Ankle (Campbell) Occasionally the ankle is ankylosed with the foot in a position of equinus and if the

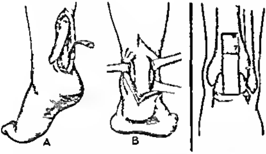


Fig 400 (*Left*) Tenotomy for lengthening of Achilles tendon in lateral plane (A) and by an anteroposterior Z (B)
Fig 401 (*Right*) Fusion of ankle joint by an anterior sliding block from tibia into astragalus

ankylosis has been due to arthritis the malleoli will be intact Campbell corrects such a deformity by an osteotomy directly through the ankle joint, preserving the malleoli and taking as much bone as necessary from the superior surface of the astragalus By thus preserving the maximum amount of bone contacts, stability and early fusion are assured An incision five inches long is made over the anterolateral aspect of the foot and ankle and carried down to the bone along the lateral side of the extensor tendons The joint is exposed subperiosteally, displacing the periosteum and overlying tissues inward and outward without injuring the tendons or the dorsalis artery, except its terminal branches After the lower end of the tibia and the superior surface of the astragalus are exposed with a thin osteotome, a cuneiform section of bone, with its base anterior, is removed through the site of the ankle joint With extreme deformity it may be necessary to lengthen the tendo achillis in order to obtain sufficient correction The wedge of bone includes part of the lower part of the tibia and part of the upper part of the astragalus between the malleoli The foot is then forcibly dorsiflexed into a position favorable for function—that is a position of approximately 15° of equinus

The wound is closed in layers and the extremity is immobilized in plaster of paris which extends to the midthigh Unless it is well padded the plaster should be split to provide for swelling At the end of three weeks this is removed, and a walking plaster which extends to the tibial tubercle is applied, and the patient may begin to be up on crutches and to bear some weight on the leg At the end of eight weeks the plaster is removed and a shoe is fitted Crutches are discarded as soon as the patient is able to do without them

Arthrodesis of Ankle (Fig 401) The incision begins about four inches above the ankle on the anterolateral aspect of the leg It is carried downward and slightly inward along the inner border of the extensor hallucis longus tendon The incision is deepened between this tendon and the tendons of the extensors of the other toes It is carried down to the bone and an incision is made in the periosteum of the tibia and carried directly down across the ankle joint and the superior surface of the astragalus the short extensor muscles being reflected outward while the dorsalis pedis artery is reflected inward. Some branches of this artery may be cut in the lower portion of the incision The bone is then exposed subperiosteally, both on the dorsum of the astragalus and on the lower end of the tibia With a thin osteotome the cartilage on the lower end of the tibia and the inner side of each malleolus and on the superior surface and sides of the body of the

astragalus is removed A sliding bone graft is then cut from the anterolateral surface of the lower portion of the tibia This graft should be about four inches long and approximately one half of an inch or more wide, being made as wide as the bone will permit It may be cut with an electric saw or with an osteotome The graft is lifted up, and should include some of the cancellous portion of the lower end of the tibia A depression is then made in the superior surface of the body and neck of the astragalus and after the foot is put in the desired position—that is approximately 15° of plantar flexion—the graft is driven down into the body of the astragalus and wedged into the groove in the tibia Bone chips are then removed from the anterior surface of the tibia and packed into the space between the astragalus and the malleoli on either side The wound is then closed in layers

The foot is then immobilized in plaster of paris in a position of 15° plantar flexion, the cast extending to the midthigh This plaster is well padded It is left on for a period of approximately two weeks The sutures are removed, and a skin tight plaster is applied If the arthrodesis has not been done for tuberculosis, this may be a walking plaster and the patient may begin to walk and bear some weight on the leg The second plaster should remain on for approximately six weeks At the end of this time union should be fairly firm, and the plaster may be removed If not, another walking plaster should be applied for four weeks When this is removed, the patient may begin to bear weight upon the extremity The crutches are discarded when the patient is able to get along without them

OPERATIONS ON FOOT

Triple Arthrodesis of Foot This operation includes fusion of the subastragaloid, calcaneocuboid, and astragaloscaphoid joints [See Chapter 7]

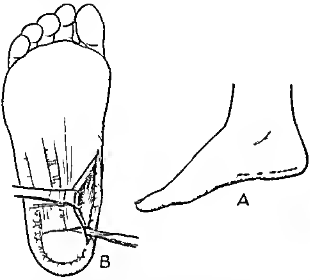
Dorsal wedge Operation This is a useful operation for the correction of a cavus deformity of the foot in which subastragaloid arthrodesis is not indicated If this arthrodesis is indicated, a triple arthrodesis can be used and the cavus corrected by removing an excess of bone from the neck of the astragalus and cuboid and the anterior portion of the os calcis However, in certain instances this combination is not desirable particularly in ankylosis of the tarsal joint with a cavus deformity and with the heel in good position or in slight equinus [See Chapter 7 for technic.—Ed]

Steindler's Stripping Operation for Pes Cavus (Fig 402) A horizontal incision is made on the inner aspect of the foot at the junction of the sole and the skin on the inner side of the foot and is carried forward approximately one and one half inches anterior to the tuberosity of the os calcis This incision is carried directly inward, parallel to the sole to expose the under surface of the plantar fascia This is separated from the layer of fat of the sole and heel throughout its breadth The fascia is then cleaned with a sponge and blunt dissector in order that it may be well defined Then the inner edge of the fascia is freed by sharp dissection The plantar fascia is cut from its origin or attachment to the tuberosity of the os calcis Likewise, the muscles beneath the plantar fascia, which are attached to the os calcis, are also stripped from their origins on this bone

It is important that the dissection extend entirely across to the outer side of the os calcis and that all of the tissues which are attached to the os calcis and which extend forward to the forefoot be removed from the under surface of the bone This includes the long plantar ligament which extends between the os calcis and the cuboid If the dissection is kept close to the bone, vessels and nerves will not be injured It is preferable to use sharp dissection, otherwise osteogenic tissue from the periosteum may be raised from the bone and cause new bone formation in the sole of the foot, and this may be painful

After the tissues have been stripped from the os calcis the foot is forcibly dorsiflexed The wound is then closed in layers and a plaster of paris boot is applied which extends from the toes to the tibial tubercle and holds the foot in a position of dorsiflexion This is worn for four weeks At the end of this time it may be removed and the patient may begin to use a shoe He uses crutches only as long as necessary An anterior metatarsal bar is placed across the sole of the shoe to help keep correction

not spurs, but broad thin shelf like projections of bone which extend transversely across the heel, are removed It is important that they be removed entirely across the tuberosity of the os calcis, and that, after their removal, the lower surface of the os calcis be left relatively smooth The subcutaneous tissues are then closed with fine silk, and the skin with a continuous suture No plaster is necessary Weight bearing is resumed in two weeks with a rubber pad in the heel of the shoe



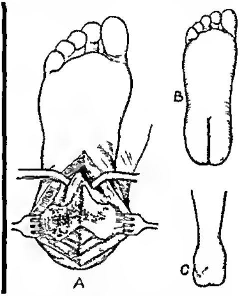


FIG 402 (*Left*) Steindler stripping of plantar fascia (A) Line of incision on inner aspect of foot (B) Skin and subcutaneous tissues retracted and dissection of attachment of muscles and fascia from bone begun

FIG 403 (*Right*) Split heel incision of Gaenslen (A) Resultant 'buried' scar (B) and (C)

portion of the plantar fascia Then, with a broad, thin osteotome the body and tuberosity of the os calcis are split longitudinally As the two halves of the bone are pried apart the subastragaloid and the calcaneocuboid joints are opened

If it is desired to avoid the calcaneocuboid joint, and to drain only the subastragaloid joint, the incision is carried directly downward in the midline of the foot Infected bone is removed with a gouge or curette, the cortical bone being left where possible The wound is packed open with vaseline gauze and the foot and ankle are immobilized in plaster of paris which extends from the toes to the tibial tubercle If desired, this incision may be carried forward to drain the midtarsal region, or the astragalus, if badly diseased, may be removed through the incision and the ankle joint may be thus drained

Hallux Rigidus [See Chapter 5]

Operation for Hammertoe [See Chapter 5]

Hoffman's Operation for Claw Toes A curved transverse incision is made across the sole of the foot just proximal to the commissure of the toes This is carried down through the deep fascia to the tendons, care being taken not to extend it too deeply and unnecessarily cut some of the nerves The tendons over each metatarsal head are then reflected and each metatarsal head is separately exposed by opening the capsule and cutting the lateral ligaments on either side The metatarsal head is then excised with bone cutting forceps, enough of the neck being removed to permit release of the contracted tissues and free motion between the bases of the phalanges and the remainder of the metatarsal bone The wound is closed in layers, no postoperative fixation is necessary This may be combined with the operation for hallux rigidus

Excision of Sesamoids Occasionally one or both sesamoids is persistently painful over a period of months or years and this may occur without fracture In such instances excision of the sesamoid is warranted This can be accomplished through a small incision approximately one inch long on the mesial border of the foot opposite the sesamoid and near the plantar surface This incision is carried directly down to the bone and the offending bone is removed from the tendon by sharp dissection If necessary, the incision may be made slightly longer and deepened to remove the lateral sesamoid also The incision is closed in layers, no postoperative fixation is necessary Weight bearing begins after stitches are removed, but the foot may remain tender for several weeks after the operation

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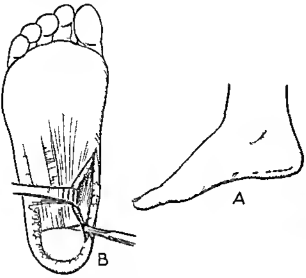

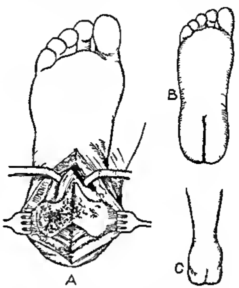

Fig 402 (*Left*) Steindler stripping of plantar fascia (A) Line of incision on inner aspect of foot (B) Skin and subcutaneous tissues retracted and dissection of attachment of muscles and fascia from bone begun

Fig 403 (*Right*) Split heel incision of Gaenslen (A) Resultant buried scar (B) and (C)

Removal of Calcaneal Spurs An incision on the inner side of the foot and extending forward about one and one half to two inches beyond the tuberosity of the os calcis is made at the junction of the skin of the sole with the normal skin on the inner side of the foot. This is carried directly inward parallel to the sole to expose the under surface of the plantar fascia. The plantar fascia is then cut across transversely severing it from its attachment to the tuberosity of the os calcis. With a sharp thin osteotome the spurs which are really not spurs, but broad thin shelf like projections of bone which extend transversely across the heel, are removed. It is important that they be removed entirely across the tuberosity of the os calcis, and that, after their removal, the lower surface of the os calcis be left relatively smooth. The subcutaneous tissues are then closed with fine silk, and the skin with a continuous suture. No plaster is necessary. Weight bearing is resumed in two weeks with a rubber pad in the heel of the shoe.

Gaenslen's Split heel Incision (Fig 403) The patient is placed in the prone position with a large sandbag under the ankle. The incision begins in the midline over the lower portion of the tendo achillis near its attachment to the os calcis. It is extended directly downward across the heel and then forward and slightly outward in line with the body of the os calcis until it is over the under aspect of the calcaneocuboid joint. The incision is carried directly down to the bone, splitting the distal portion of the tendo achillis and the proximal

portion of the plantar fascia Then, with a broad, thin osteotome the body and tuberosity of the os calcis are split longitudinally As the two halves of the bone are pried apart the subastragaloid and the calcaneocuboid joints are opened

If it is desired to avoid the calcaneocuboid joint and to drain only the subastragaloid joint the incision is carried directly downward in the midline of the foot Infected bone is removed with a gouge or curette the cortical bone being left where possible The wound is packed open with vaseline gauze and the foot and ankle are immobilized in plaster of paris which extends from the toes to the tibial tubercle If desired this incision may be carried forward to drain the midtarsal region or the astragalus if badly diseased may be removed through the incision and the ankle joint may be thus drained

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16

Hematogenous Osteomyelitis

FENWICK BEEKMAN, M D

ACUTE FORM

Definition Acute hematogenous osteomyelitis may be defined as an inflammatory process involving the marrow cavities, the haversian canals, or the subperiosteal space of a bone, in which the bacteria responsible for the inflammation are brought to and deposited within the bone by the blood stream This, of necessity, predisposes that the infecting organism first must have entered the circulation and contaminated the blood itself Therefore the osteomyelitis is preceded, in every case, by a bacteriemia

The bacteriemia however, is evident in only a few cases before the onset of the osteomyelitis, as in those in which the bone involvement complicates certain types of endocarditis, typhoid fever, or epidemic influenza More often the onset of the osteomyelitis is precipitate and appears without prodromal symptoms The preceding bacteriemia in these cases is not recognized because of the absence of clinical signs, and, even after the onset of the osteomyelitis bacteria are not always demonstrable in the blood stream by means of blood culture, as the organisms often appear to have left the blood stream before the patient comes under observation

Because of this, it is believed that in some cases of hematogenous osteomyelitis the bacteriemia responsible for the production of the lesion is transitory in character In these cases the surgeon has only the osteomyelitis to deal with in his treatment On the other hand, the bacteriemia continues in the so-called fulminating type of the disease, giving the patient the overwhelming symptoms of a septicemia and endangering his life by the possible production of a pyemia Here a positive blood culture is usually obtained, though negative findings do not necessary rule out the presence of a bacteriemia

Fulminating Type of Disease The mortality in cases of acute hematogenous osteomyelitis occurs among these cases of the fulminating type Death of the patient is almost always the result of the septicemia or a supervening pyemia It is seldom, if ever, directly due to the suppurative lesion within the bone

Pyrah and Pain report autopsies in 51 cases of individuals who had suffered from acute hematogenous osteomyelitis All showed pyemic lesions in the soft parts or organs except six cases which showed no lesions at all[1] In a report made by the author death occurred in 38 cases Of these, septicemia accounted for 19, pyemia for 15, endocarditis for 1, meningitis for 1 and chronic sepsis for 2

This knowledge has entirely altered our concept of the condition and has, consequently, changed our notions concerning the procedure that should be followed in the treatment of the patient suffering from the fulminating type of acute hematogenous osteomyelitis In consequence, instead of focusing our entire attention upon the elimination of the local lesion within the bone, as was done in the past, we now di-

rect our endeavors toward treatment designed to combat the blood stream infection

Fraser, who in 1934 first drew attention to the importance of the underlying condition, said

> A haemic infection of a bone presupposes that staphylococcal organisms are already circulating in the blood stream and that their localization in the bone is but a local manifestation of the general disturbance To the surgeon the local infection has been the important item in the clinical picture it is upon this that he has concentrated his ingenuity and his skill but is it right that we should regard the local focus as a most deplorable and regrettable manifestation? There is such a thing as a fixation abscess—nature's method of producing a defensive area from which the factors of immunity are organized and developed The prognosis is improved if we have the courage to delay operation until the focus is reasonably well established and having chosen the most opportune time to restrict the operation to one involving the minimum of interference and yet securing drainage and relief of tension"

Robertson who formerly strongly advocated early operation now agrees with Fraser, expressing his views as follows

> Recently the writer has felt that an early operation gives no help to the patient The problem in an early case is one of combating a blood stream infection dealing with the toxins and organisms that are present, and until some approach to an equilibrium has been reached, surgery, in so far as incision of a local lesion goes has nothing to offer When the condition has reached a point where pus is present, then a simple drainage may be of advantage [3]

Another factor of importance in regard to treatment of hemic infections of bone, which has become of great moment since the advent of chemotherapy, is the early recognition of the type and strain of the bacteria responsible for the disease in the particular patient under treatment This information is necessary not only in order that the proper drug may be prescribed at the earliest possible opportunity, but also so that the procedure of treatment may be modified in order to adapt it to the behavior of the organism producing the disease

It is well known that different types and even different strains of bacteria causing inflammatory reactions in the tissues of the body act differently and provoke dissimilar reactions in the body Consequently the procedure of treatment should be planned so as to be the most efficacious for combating the specific type and strain of bacteria that may be the cause of the condition in the particular case under consideration It is well known that the *Staphylococcus aureus* which is responsible for 85 per cent of the cases of acute hematogenous osteomyelitis when deposited at a point of fixation by the blood stream, causes a rapidly localizing inflammation which soon breaks down and forms an abscess The inflammation resulting from the fixation of the streptococcus is diffused like a cellulitis it is slow in localizing and often may not localize at all though a lesion may be demonstrable within the bone by means of the x ray

Robertson in discussing this point, writes

> There is very little similarity between the two conditions and unless we make a clear cut distinction between staphylococcal osteomyelitis and streptococcal osteomyelitis there cannot be any clear understanding of the serological problems that enter into the treatment It is useless from the standpoint of treatment to group all cases of osteomyelitis and to consider the mortality of the whole group These diseases are entirely different in their clinical manifestations [3]

Though Robertson is writing in reference to the use of serologic therapy, the same argument is valid whether chemotherapy, operative treatment, complete immobilization of the involved part, or a combination of these methods is used Procedures must be modified to conform to the indications presented by the reactions of the body toward the particular type or strain of bacteria that may be present in the case under treatment if success is to be achieved It is quite evident that all cases of acute os-

teomyelitis cannot be treated alike if due to different types or strains of bacteria. Hence, it is of the utmost importance that the type of organism causing the osteomyelitis in each particular case be discovered at the earliest possible time in the course of the disease. Its nature may be already known because of a definite condition preceding the osteomyelitis, such as typhoid fever or a streptococcus pneumonia following influenza, or it may be strongly suspected when the osteomyelitis follows a streptococcus tonsillitis or perhaps a furunculosis due to the *Staphylococcus aureus*.

More often, however, the type of infecting organism can be ascertained only by means of a thorough investigation of the particular patient under observation. The blood culture is of the greatest help, if it happens to be positive, but even then this takes time. Smears and cultures may be obtained, perhaps, from a superficial abscess, from the exudate in a distended joint, or even from an abscess in the soft parts overlying the focus in the bone. An opinion as to the type of involving organism often may be reached, in a large number of cases, long before the report from a culture is received, by analyzing the facts obtained from the clinical history and physical examination of the patient. If no smear is available, the procedure to be followed is based on the clinical indications as to the probability of the infection being of streptococcal or staphylococcal origin. This cause should be followed until, and if, the culture results indicate the need for change.

TREATMENT. The treatment of the fulminating type of the disease resolves itself, therefore, (1) into combating the blood stream infection, and (2) into caring for and healing the local lesion in the bone. It must be remembered always that a general pyemia or a metastatic abscess involving one of the vital organs of the body may be present in addition to the osteomyelitis. These more serious complications must be diagnosed and treated as well as the local lesion. To combat and overcome the septicemia from the very onset, in order to prevent the development of further pyemic abscesses, is absolutely essential, especially since they may involve some vital organ and cause the death of the patient.

In order to accomplish this, the general resistance of the body must be improved, the factors that have to do with immunity must be stimulated, so that bacterial toxins may be neutralized, and the organisms that may be circulating in the blood stream must be destroyed and thereby prevented from being deposited at new points in bone, soft parts, or viscera to form new foci. None of this can be accomplished by attempting to eliminate the focus within the bone, as was formerly quite generally advised, and as is still advised in some quarters. A great deal of harm may be done, as a matter of fact, for the lesion is the result of the bacteriemia and should be considered as a point of fixation from which, as Fraser says, "the factors of immunity are organized and developed."[2]

If this be true, as is now quite widely believed, imprudent operative intervention accomplishes nothing and surely does harm. It not only destroys the local resistance of the tissues and disseminates the bacteria contained within the focus throughout the body via the blood stream, but it also brings to naught nature's method of combating the general infection by establishing points of bacterial fixation, from which the factors of immunity are developed by the tissues about them. It is therefore believed by many of those who have had much experience in treating hemic infections, especially those due to the staphylococcus, that the bone lesion in the acute phase of hematogenous osteomyelitis should be allowed to form and to develop into a well localized abscess before it is subjected to the traumatization of operation. The local lesion should

in fact be protected in every way against the slightest irritation and, therefore, the part containing the involved bone should be completely immobilized The surgeon should at all times bear in mind that the final elimination of the blood stream infection rests largely with the bodily resistance of the patient and that all that he can accomplish is to assist nature by helping to build up the factors of immunity or to lessen the resistive powers of the infecting organism Nothing should be done, therefore, which may lessen or hamper nature's fight to overcome the bacteria that are circulating in the blood stream An ill advised operative procedure performed at a time before the defenses of the body have the infection under control severely hampers nature's efforts

[Ill advised operative procedures are certainly to be avoided It might be well however, to say something at this point about the belief still held by many that early operation is indicated in a certain number of cases

The medical adage, Once an osteomyelitis, always an osteomyelitis was based on the fact that a large percentage of these cases represented so extensive a bone involvement that surgical removal of the disease was impossible, and that drainage sequestrectomies and partial excision of infected bone were the only surgical procedures that could be utilized This extensive involvement has been held to be the result of two processes—that of infection and that of massive death of bone, involving a large part or all of the diaphysis—as a result of circulatory obstruction The latter is the result of collapse of the bone vascular channels progressively by the tension created within the bone due to the exudation and edema resulting from the combined processes of the infection and the initial thrombosis of terminal circulatory channels in the para epiphyseal region where the infection starts This may be a rapidly progressive affair, shutting off the communication between medullary and cortical circulation via the periosteum, resulting in massive death of all or part of the shaft

That this *can* occur is readily demonstrated If a fraction of a minim of croton oil is introduced through a small drill hole in the para epiphyseal region of the shaft of a long bone of a young animal, and the drill hole is then firmly closed by a bone wax plug to again make the bone a closed cavity one of three conditions may result (1) A local area of necrosis and sterile abscess may form, (2) the same condition plus massive necrosis of a large part of the shaft in that end of the bone may be found or (3) the local abscess plus massive necrosis of the whole shaft from epiphysis to epiphysis may be found Moreover this result is found by the end of 48 hours

If, when the croton oil is placed in the medullary canal, several additional drill holes are made, *and none of them are blocked* (so that escape for inflammatory exudate and for edema fluid is allowed), the resultant lesion is almost invariably that of the local abscess unaccompanied by massive bone death, but with soft part abscess The parallel in the case of a virulent organism is obvious That the virulence of the organism may be such that it can kill the patient rapidly in many cases attests to a toxicity comparable to the croton oil

On the basis of preventing the massive death of a large part or all of the diaphysis and of limiting the process to the actual area of early *infection* as much as possible, early operation is indicated only in those cases presenting, when seen, the clinical evidence of extreme tension within the bone regardless of the evidence of severe systemic infection The operative indication is for the relief of intra-osseous tension threatening the *integrity* of circulation, and is not for infection or osteomyelitis The procedure must be based on that

premise, and should consist in a rapid and simple exposure of the para epiphyseal region in the area indicated by symptoms (see below), the outlining *in the cortex only* of a rectangle of bone one by two and a half centimeters with a thin sharp osteotome tilted so as to cut along cortex and not to drive through into the marrow cavity, the lifting out of this cortical window, and the packing of the wound loosely so that it is kept open

The whole procedure should not take 15 minutes It should not damage the medullary canal or its structures Under no circumstance should curetting or any other procedure be used Any operation for removal of infected or necrosed bone should be deferred until, as advised by the author of this chapter, such process is clearly localized and defined by x ray In addition to the procedure here described all other treatment as advised in this chapter should be carried out, this "taking the lid off the boiling tea kettle to let the steam out' being added only in those cases evidencing the clinical evidence of extreme tension

Which are those cases? They are those showing, when first seen, excruciating pain and exquisite local tenderness The two adjectives are used advisedly Mere pain and tenderness are not sufficient—the pain and tenderness must be extreme They are *to be considered entirely independently* of the systemic symptoms of temperature, toxemia, prostration, and blood count They may be present with or without marked systemic symptoms The relief of the tension must be considered as having no effect on the systemic disease—merely as an attempt to prevent massive bone death If the extreme pain and tenderness are not present operation is not indicated If they have been present (by history) but are diminishing or have disappeared when the patient is seen, operation is not indicated From what has been said it is also obvious that operation, even in the presence of these symptoms, is not indicated if the degree of prostration and shock present render the patient practically moribund The avoidance of operation should be as intelligently exercised as the use of operation It may be said that these criteria limit the use of early operation to relatively few cases This is quite so In those few, however, a great deal can be accomplished It is to be emphasized that in those relatively few cases this early operative procedure is merely in addition to the rationale of treatment described in this article, and not in place of it At the time of operation the placing of local chemotherapy is a logical procedure, provided it is blown or shaken into the area and is not pushed into, or stirred around in, the medullary canal

Multiple drill holes in the early operative attempt to relieve tension are inadvisable for two reasons (1) They provide inadequate relief of tension, and (2) they stir up the medullary canal If the procedure is done, it should provide adequate escape for exudate and edema, and should inflict no additional damage within the medullary canal

With these views, held still by many thinking surgeons, the editor is in complete accord —Ed]

Use of Sulfonamides With the introduction, during recent years, of the new *chemical products—sulfanilamide, sulfapyridine*, sulfathiazole, and sulfadiazene—the surgeon has been supplied with a valuable aid in fighting the bacterial invasion of the body These drugs, though they do not actually destroy the organisms circulating in the blood stream or lodged in the tissues, do render assistance by lowering the virulence of the bacteria and diminishing their activity, thereby allowing the body sufficient time to build up the factors of immunity that eventually must overcome the infection Their use, however, does not necessarily do away with the need for operation in order to drain a fully established lesion

in some part of the body, for though these drugs may prevent the *establishment* of such a lesion or may even arrest its rate of *development*, a *completely* formed abscess must eventually be incised and drained if it *is to heal* With these facts in mind, the treatment that is to be used in acute hematogenous osteomyelitis may be now described in detail

[See Chapter 22 for further discussion of chemotherapy and for the use of penicillin in these cases —Ed]

Treatment of Septicemia in Acute Hematogenous Osteomyelitis

Hospitalization An individual suffering from acute hematogeoous osteomyelitis should always be hospitalized, if at all possible, when first seen Good nursing is most essential to his welfare, and it is also important to have him where his condition can be investigated most thoroughly and where all the facilities necessary for treatment are at hand

Nutrition The nutrition of the patient often may be difficult to maintain and therefore the diet should consist of foods of high caloric values, prepared so that they can be easily digested and assimilated Proteins, as well as sugars, should be prescribed The fluid intake must be forced so as to stimulate elimination through the kidneys If fluids are refused by mouth, or rejected due to vomiting, they must be given iotravenously Two to three liters of normal saline solution or 5 per cent glucose solution can be given through a vein each 24 hours by means of a continuous drip

Transfusions Transfusions have proved themselves to be of the greatest value in helping patients suffering from acute infections The blood from a donor supplies normal constituents in which the patient s blood may be lacking Some believe that factors of immunity can be transferred from donor to recipient in this manner, but this has not yet been proved to general satisfaction Some types of bacteria responsible for the septicemia accompanying hematogenous osteomyelitis have, or acquire, hemolyzing qualities, and, in consequence, break down the red blood cells These can be replaced only by whole blood given by means of transfusion The plasma of the blood provides serum proteins which the patient may need at some time during the course of the disease This is especially so if the diet by mouth is refused or if there is frequent vomiting

The proper nutrition of the patient in such a situation can be kept up only by supplyiog carbohydrates by intravenous glucose, and serum proteins by intravenous blood plasma if a sufficient number of red blood cells are present If the red cell count is deficient, transfusions of whole blood are, of course, indicated During the height of the toxemia, it is in general wise to prescribe frequent small traosfusions, of 150 to 250 cc each, depending upon the weight of the individual, at intervals of perhaps every three to five days, regardless of the patieot's actual need for plasma protein or red cells

Examination. As soon as the patient is admitted to the hospital, he must be completely and carefully examined The surgeon must know exactly the extent of the lesions he is dealing with, as often there may be *more than one* *The local condition must be* particularly noted, but a systematic general investigation should be made as well Particular attention should be paid to the heart, as suppurative pericarditis not infrequently accompanies hematogenous osteomyelitis The hemoglobin value and both red and white cell counts should be obtained Most important however is the blood culture, which should be taken immediately after admission If there is suspicion that the infection is the result of a hemolytic streptococcus, a culture should also be obtained from the tonsils and pharynx, or from the discharge from an ear, if present If a superficial wound be present, whether it is insignificant in size or not, or if there is a furuncle on the surface of the body, these

certainly should be investigated bacteriologically by smear and culture

Signs of the Disease The first definite sign of acute hematogenous osteomyelitis may be a suppurative arthritis of some joint adjacent to the involved bone The hip, knee, and shoulder joints, in the order named, are the ones most commonly invaded from foci in subjacent bones As instances, an osteomyelitis beginning in the metaphysis of the neck of the femur will almost always perforate the cortex close to the epiphyseal cartilage plate of the head of the bone and produce a suppurative arthritis of the hip joint an osteomyelitis of the lower metaphysis of the femur may perforate the anterior or posterior walls of the cortex close to the epiphyseal cartilage plate to produce suppuration within the knee joint

Occasionally the bone lesion develops in an epiphysis and may perforate directly into the subjacent joint The contents of such a joint must be investigated When a joint capsule is found distended with fluid, the joint should be aspirated in order to ascertain the character of the exudate Cultures are obtained from this exudate, but a microscopic examination of a drop of it smeared upon a glass slide may often give immediate information concerning the type of bacteria responsible for the osteomyelitis

An x ray examination of the local focus in the bone, though it will probably show nothing abnormal at so early a period in the disease may nevertheless give the surgeon information which will be of value later on in treatment It should therefore be made, if it does not call for undue movement of the patient

Immobilization These investigations having been completed immediately after admission of the patient, the part containing the involved bone is completely immobilized within a plaster encasement applied over cotton batting The casing may be bivalved at once in order that if further examination of the involved bone seems necessary at a later time the top of the plaster shell may be removed without disturbing the part It must be applied so that all motion is arrested in the contiguous joints, thereby relaxing the muscle tension The slightest movement of the involved part will cause pain, which in turn will stimulate spasm of the overlying muscles The plaster, therefore, should extend well above and well below the point of the disease in the part, so that complete immobilization is obtained

For instance, if the lesion is at the lower end of the femur, the plaster should be in the form of a hip spica which extends down to the level of the toes If the hip is involved, it is well to have the plaster extend from the costal margin down to cover the foot of the involved limb and to the level of the midthigh on the opposite extremity Casings for the upper extremity, especially if the proximal end of the humerus is involved, should include the chest and extend down to support the hand [Plaster beds for spine cases and plaster beds with thigh encasements for pelvic cases, are the best forms of immobilization in these instances See Chapter 14 for details of these —Ed]

Traction, with the limb extended by means of adhesive plaster and weights, should not be used This form of appliance fails to give sufficient immobilization to place the diseased part completely at rest

If, on aspiration, a joint is found to contain fluid which is not purulent, it should be emptied of its contents in order to relieve the tension upon its capsule before being immobilized in the plaster encasement However, if it contains a purulent exudate it must be cared for as will be described later on

The fluid balance of the tissues of the individual must be brought into equilibrium through the use of intravenous infusions of saline or glucose after immobilization of the part To accomplish this may take as long as from six to 12 hours, or even longer If the individual has been sick for more than

a few days, the parenteral fluids should be augmented by a transfusion of about 200 or 300 cc of blood, the actual amount depending upon the age or size of the individual

Chemotherapy Chemotherapy can be commenced as soon as the diagnosis has been made Since sulfathiazole is equally efficient in combating staphylococcus and streptococcus infections in almost all cases, it may be used immediately, even though the specific type of bacteria responsible for the condition in the particular case may not have been as yet ascertained The initial dose by mouth, in the case of an adult, should be 3 Gm (45 gr), followed by doses of 1 Gm (15 gr) every four hours day and night The patient will therefore receive 8 Gm (120 gr) during the first 24 hours and 6 Gm (90 gr) during every succeeding 24 hours Because sulfathiazole is much more rapidly excreted than either sulfanilamide or sulfapyridine, the dosage to be given a large and robust individual may have to be even larger, perhaps as much as 1 5 Gm (22 5 gr) every four hours Relatively large dosages may be prescribed to children, as they appear to be less liable to the toxic effects of the drug As large a dose as 7 Gm (105 gr) during the first 24 hours and 6 Gm (90 gr) on each succeeding day has been prescribed to children of ten years of age, who were suffering from severe septicemia, without the appearance of unfavorable symptoms An estimation of the concentration of the drug in the blood should be obtained at the end of 36 to 48 hours and thereafter at intervals of every two days The urine should be examined at the same intervals for crystals, red cells, or albumin Though it is said to be essential to keep the concentration as high as 5 to 8 mg per 100 cc. of blood, this is seldom possible when using sulfathiazole because of the rapidity of its excretion by the body However, remarkable success has been obtained with a concentration as low as 2 mg per 100 cc of blood Sodium sulfathiazole is available for intravenous medication if for any reason the patient is unable to take the drug by mouth We have not had experience in the use of sulfathiazole in this way, but it has been used under careful check with apparent safety [Sulfadiazine is now used pretty generally since it is perhaps less toxic than any of the drugs mentioned here See Chapter 22 —Ed]

The surgeon is cautioned to be ever watchful for toxic symptoms when using any of the drugs of the sulfonamide group A rapidly progressive anemia without obvious signs or an agranulocytosis may develop Therefore, frequent red and white cell counts should be obtained while the patient is under treatment At the first sign of a relatively sharp drop in the number of polymorphonuclear leukocytes the drug should be withdrawn as this may indicate a depressing effect by the drug upon the patient's bone marrow A secondary anemia is fairly common but it is not so serious a condition as the decrease in polymorphonuclear leukocytes, for it can be easily treated by means of blood transfusions Prompt discontinuance of the drug is indicated if hematuria occurs, as this symptom denotes damage to the kidney through the deposition of acetylsulfathiazole crystals in its tubules Jaundice may also occur as the result of a toxic hepatitis and indicates the need for immediate discontinuance of the drug

The patient should continue taking sulfathiazole until the temperature has reached and remained at the normal level for at least three to five days

If culture results show the infection to be caused by the *Streptococcus haemolyticus* or a pneumococcus, the drug may be changed to another of this group It has been found, however, that sulfathiazole is quite as efficient as, and can be used more generally than, either sulfanilamide or sulfapyridine, and it is therefore well to start by using it In an occasional case of infection by the hemolyzing streptococcus there may be no improvement following its use, or toxic

symptoms may develop, and then a change to sulfanilamide must be made [For complete discussion of chemotherapy and the use of penicillin see Chapter 22 —Ed]

Bacteriophage intravenously has been used by some with success in cases of staphylococcus bacteriemia Longacre, Zaytzeff Jern, and Meleney have recently reported 36 cases of staphylococcus septicemia treated in this manner, with a mortality rate of 47 2 per cent, compared with 69 other cases in which bacteriophage was not used and in which the death rate was 81 4 per cent [4] Perry S MacNeal reports a mortality rate of 8 3 per cent in a series of 12 cases [5] Others, however have not found the use of bacteriophage as successful as these reports would seem to indicate It is not now in general use [See discussion of chemotherapy, Chapter 22 —Ed]

Local Lesion

In the short time since the introduction of the use of the sulfonamide group of chemicals, a considerable number of cases of acute hematogenous osteomyelitis of the fulminating type, caused by both the *Streptococcus haemolyticus* and the staphylococcus, have been reported, in which the osseous lesions though they could be visualized later by means of the x ray, failed to break down and suppurate Even though sequestra appeared to be present in these cases by x ray, the lesions, nevertheless, healed completely without ever having formed abscesses The dead fragments of bone were apparently revascularized, absorbed and new bone laid down

Treatment was started in these cases very early in the course of the disease, evidently before suppuration had begun, and the progress of the inflammation was arrested In other cases, well formed suppurative lesions were present when the patients were first seen by the surgeon These were either subperiosteal abscesses or pyarthroses containing thick pus Following the establishment of a fluid balance in the tissues of the patients, the local lesions were simply drained, the parts were completely immobilized, and chemotherapy was started All of these patients rapidly recovered with little morbidity, when compared with the results obtained in the past by other methods.

The time to operate on the acute case is after a well formed abscess is present. Suppuration never occurs in some cases of hematogenous osteomyelitis caused by the *Streptococcus haemolyticus,* and in others localization of the lesion does not occur for some length of time On the other hand, abscess formation of lesions caused by the staphylococcus occurs much more quickly and certainly However, there is no specified time in the course of the disease which can be definitely said to be the right moment to operate Robertson states "No case should be operated upon in which there is not a definite abscess" [3] Phemister writes "Usually pus will localize and appear external to the bone in from three to seven days Aspiration is a helpful adjunct in detecting it When the abscess can be located, it should be opened and drained " [6]

As has been stated, there may be present one of two lesions a subperiosteal abscess or a pyarthrosis In the latter case, the involved joint easily can be aspirated to find out the condition of the exudate it is not always so easy to obtain material from a subperiosteal abscess It therefore seems a good rule when such a localized lesion is present, if the individual has been sick for at least five or six days, if the infecting organism proves to be the staphylococcus, and if no improvement has been shown from immobilization of the involved part and the use of sulfathiazole, to operate upon and drain it as soon as the patient s tissue fluids are in a state of balance

It must be borne in mind in operating upon the acute lesion that the focus usually starts at one of the ends of the bone—that is, in one of the metaphyses—and, consequently, the incision should be planned in

such a manner that it will drain the focus directly, through the shortest route If there are no other signs which may indicate the location of the lesion, the point of maximum tenderness should be ascertained before the patient is placed under an anesthetic, and should be regarded as the point at which the incision is to be made However, the anatomic situation must be considered also in each case, in order to avoid possible injury to important structures In planning the incision one must bear in mind particularly the relationship of the joint capsule to the incision, so that the joint may not be accidentally entered and contaminated General anesthesia should be used in all cases

It is well to make a relatively long incision down to the fascia covering the muscles, then, if possible, the approach is continued down to the periosteum between adjacent muscle bellies by means of blunt dissection If, however, this is not possible, the overlying muscle or aponeurosis is split in the direction of its fibers for a distance somewhat shorter than the length of the skin incision As each layer is opened, the edges of the wound are gently retracted in order that the surgeon may observe what he is doing and may also obtain hemostasis

On reaching the periosteum, an abscess should be found beneath it if the time of operation is well chosen This should be incised, but not for a distance longer than the incision in the overlying muscle If the directions given here are followed, the wound leading down to the bone will be in the form of an irregular inverted cone with its base on the skin surface, which is the most efficient form for drainage If no abscess is found on exposing the periosteum, but the membrane is seen to be edematous, it is incised longitudinally for a short distance, particular care being taken not to damage the attachment of the capsule of the joint to the bone or to the epiphysis The periosteum itself must not be detached at any point where it is firmly adherent to the cortex The edges of the wound in the periosteum are then gently separated and a small button of bone is removed with a trephine of one half inch diameter, or a trap door is raised in the cortex of the metaphysis by means of a sharp chisel or gouge Damage to the epiphyseal cartilage plate should be avoided Nothing further should be done to the bone If pus be present, it will well out If pus be not found further exploration within the metaphysis will only do harm It must be remembered that the operation is to obtain free, unobstructed drainage from the lesion, accomplished with as little damage to the tissues and to the circulation of the part as is humanly possible

Having accomplished this, the edges of the wound in the soft parts are lightly packed apart with vaselined gauze The part is then dressed loosely with a generous amount of dry, sterile gauze held in place with a gauze roller bandage The limb is then completely immobilized in a plaster encasement to eliminate all motion in the adjacent joints, so that the muscles may entirely relax

The technic to be used in those cases in which the bone focus has invaded an adjacent joint early in the course of the disease, producing a pyarthrosis, is quite similar to that described for the drainage of a subperiosteal abscess Experience has taught us that only the joint need be drained in these cases, and that nothing further need be done to drain the focus in the metaphysis of the bone The surgeon, having satisfied himself that the joint contents are purulent, proceeds as follows

The capsule of the joint is widely incised without entering the joint with finger or instrument In the case of the knee joint, parallel incisions are used on either side of the patella The overlying skin and subcutaneous tissues are incised from a point well above the condyles of the femur to just below the level of the lower border of the patella Finally, the capsular ligament of the joint is freely incised, the incision being

carried upward sufficiently high to open adequately the quadriceps bursa The edges of the wounds are packed apart with vaselined gauze down to the capsular opening but none of the gauze enters the cavity of the joint The wounds are then dressed and the joint immobilized in plaster, as has been already described for drainage of a subperiosteal abscess [See suppurative arthritis, Chapter 15 —Ed]

This technic for the drainage of the lesion and the subsequent immobilization of the part is that described by H Winnett Orr for the care of the local lesion in acute hematogenous osteomyelitis The subsequent care of the wound is most important, for harm can be done by meddlesome surgery The part having been encased in plaster, must be left alone if the operation for drainage has been well done, the wound will take care of itself far better than the surgeon can A window should certainly never be cut in the encasement for inspection or dressing of the wound, for, through this, the surface of the wound will be irritated, and contamination with a secondary organism may occur Orr states

> Following operation, with a sick patient, the desire to be doing something often leads to excesses of treatment that are undesirable Even if all the symptoms persist following such an operation nothing is to be gained by further disturbance of the wound Dressings, which are nearly always resorted to should therefore, not be done [7]

The relief to the patient through this complete rest of the diseased part (lack of wound irritation by dressings and muscular relaxation because of immobilization) is soon apparent in both physical and psychologic improvement, there is no pain and no fear of pain from movements or dressings

The plaster encasement should not be removed to dress the wound until the odor from the discharge is so strong and offensive that it is a nuisance to the patient and his attendants [The application of a bag of gauze or cloth containing activated charcoal or one of the deodorants advertised for body odors will do much to cut down this offensive odor This is bandaged in place over the plaster —Ed] The first dressing is seldom done before the end of the third week following operation The encasement having been bivalved, the patient is carried to the operating room If he is a child or a nervous individual, it may be helpful to use general anesthesia Careful aseptic technic should be employed, and no undue movement of the diseased part should be allowed The joints which have been immobilized should on no account be moved The discharge soaked dressings having been removed, the surgeon cleanses the skin about the wound from which the packing has not been removed. Equal parts of a solution of hydrogen peroxide and tincture of green soap soften the crusts that adhere to the skin, which then may be removed by shaving with a sterile razor The skin is then flushed off with a bland sterile solution and after that the packing may be removed The wound surfaces at this time should be seen to be covered with healthy granulations that bleed freely and, consequently, need no cleansing The cavity again is lightly packed with vaselined gauze, the wound is re dressed with sterile gauze, and a plaster casing is applied as was done originally Subsequent dressings are carried out in a similar manner, though the interval between them is longer each successive time This course should be continued until the wound is completely healed

The results obtained from this form of procedure in the treatment of acute hematogenous osteomyelitis have, in the author s experience more than justified its use A more or less modified form of the Orr method was instituted on the Children's Surgical Service of Bellevue Hospital in the year 1933 As confidence was acquired more and more of the recommendations of Orr were accepted In the year 1935 his complete technic was adopted. Since using this procedure in all cases, more attention has been paid to the fluid balance

of the patient Sulfanilamide was first used in streptococcus osteomyelitis in the year 1937 and sulfathiazole for staphylococcus osteomyelitis in the early part of 1940

Previous to 1933 the mortality in 41 cases of staphylococcus osteomyelitis with positive blood cultures was 46 5 per cent Since then, in 14 cases, it has been 21 4 per cent In one of the latter cases, in which sulfathiazole was used, recovery occurred without need for any operation for drainage The mortality in nine cases of *Streptococcus haemolyticus* osteomyelitis with positive blood culture was 44 5 per cent before the year 1933 and 28 5 per cent in seven cases since then Secondary metastatic lesions have not occurred in any cases since complete immobilization has been used, and secondary operations for the removal of sequestra have been much less frequent The patients have been much more comfortable, they have not had the daily fear of dressings, their general nutrition has been more easily maintained, convalescence has been shortened The following case history is given as an example

A nine-year old colored boy was admitted to the hospital on November 7, 1940, presenting a rash Four days previously he had had malaise and abdominal cramps The next day he had a rash on his shoulders which was diagnosed scarlet fever He was moderately ill, with a temperature of 102°, and showed a strawberry like tongue He had, however, some swelling of the left knee On questioning his parents, it was discovered that he had fallen from a "scooter" five days previously, following which there had been pain in the left knee for one day On November 8, the day after admission, a definite point of localized tenderness could be elicited over the medial condyle of the left tibia A diagnosis of acute osteomyelitis of the tibia was then made

A blood culture was taken and chemotherapy was begun, the boy being given a full dosage of sulfanilamide The following day there was some swelling around the point where the tenderness had been The area was aspirated without obtaining pus Nevertheless, the clinical diagnosis of acute osteomyelitis of the tibia was adhered to, and a plaster encasement was applied from the upper thigh to the toes This immediately relieved the boy of all pain The temperature at this time had risen to 105° The following day the medication was changed to sulfathiazole, 4 Gm of the drug being given daily The patient, however, continued to have a persistent hyperpyrexia which was spiking in type between 100 and 104° (Fig 404) Blood culture was reported as containing *Staphylococcus aureus* On November 10, because of continuation of the temperature, the sulfathiazole was changed to sulfadiazine, in the same dosage—10 gr every four hours Three days later, November 13, sulfathiazole was used again The temperature now commenced to fall and, on November

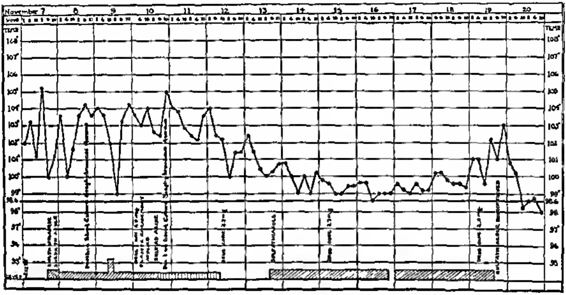


Fig 404 Clinical chart of an osteomyelitis case

15, it had reached normal, to rise again on November 19 This rise however, proved to be due to the sulfathiazole, since, when the drug was discontinued the temperature fell immediately A second positive blood culture was obtained on November 11, but all subsequent ones were negative

The patient received two blood transfusions

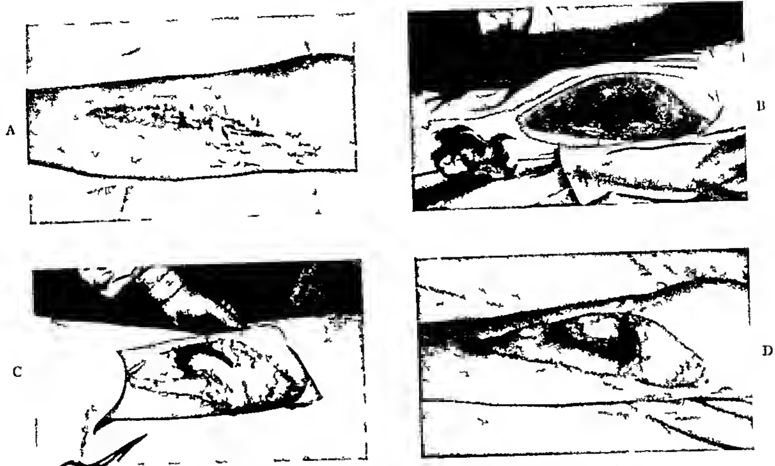
Fig 405 X ray of early osteomyelitis of upper tibia

of 200 cc of whole blood—one on November 17 and one on November 19 After November 19 the temperature remained normal A roentgenogram obtained on November 8 did not demonstrate any changes in the bone but another one obtained on November 14 showed irregular patches of osteoporosis of the upper metaphysis and a slight raising of the periosteum (Fig 405)

Brodie s Abscess

A Brodie s abscess is a localized abscess within a bone, which has been completely circumscribed and walled off with dense osseous tissue These solitary abscesses probably represent local lesions of acute hematogenous staphylococcus osteomyelitis, which the local resistance of the tissues mastered early and enveloped with a protective wall before the infection had time to spread

The position of the lesion is first located by ascertaining any point of local tenderness present on the surface, or by means of x ray, to determine the site of the incision The patient having been anesthetized, an Esmarch bandage is applied to give the surgeon a bloodless field The incision in the soft tissues, which is carried down directly to the periosteum overlying the abscess should be as short in length as is suitable to obtain exposure of the lesion The periosteum is then incised and the cut edges are sufficiently separated to allow the cortex of the bone to be pierced with a small trephine or for an opening to be made by a gouge The abscess cavity is usually found to contain an attenuated exudate, and its wall is commonly lined with pale and watery granulations The overlying bone forming the roof of the cavity is then freely removed so that the abscess cavity is widely opened The contents including the granulation tissue lining are cleaned out with a curette The cavity is then loosely packed with a strip of vaselined gauze, the end of which is brought out through the wound in the soft tissue If the abscess has been of long duration, and there have been no signs of acute inflammation a stitch of silk suture material may be placed in the skin at either angle of the wound The part is then dressed with dry sterile gauze The vaselined pack



(A) Clinical photograph of right leg three months after shell fragment wounds
(B) Saucerized wound
(C) *Completed* skin graft four days after final saucerization
(D) Healing nearly complete
(Courtesy Ann Surg 122 1 1945)

From the Article Traumatic Osteomyelitis The Use of Skin Grafts—
Part I Technique and Results by Doctors Rosati Kelly and Murray

ing and stitches may be removed at the end of a week or ten days Healing usually occurs rapidly and completely. [Chemotherapy is frequently used in the cavity at the present time See Chapter 22 —Ed]

CHRONIC OSTEOMYELITIS

A chronic suppurative process, with formation of sinuses, frequently follows acute osteomyelitis The continuance of this suppuration may be the result of a retained sequestrum or, on the other hand, may be due to the persistent dead space represented by a cavity within the involucrum, which is surrounded by a dense, hard wall of bone These cavities fail to heal spontaneously, because of the lack of blood supply in their sclerosed walls They are often due to the too long retention of a sequestrum which, preventing healing and causing a prolongation of the suppuration, results in the formation of sclerotic bone Because of the density of the walls of these cavities, roentgenograms often fail to reveal sequestra which may be present

The time of choice for performing the operation of sequestrectomy should be as soon as the dead bone has completely separated from the living, provided that an involucrum has been laid down that is strong enough to provide continuity and rigidity of bone The sequestrum often acts as an internal splint that serves to prevent the occurrence of a pathologic fracture if the involucrum is weak If the fracture of a newly formed involucrum should happen, displacement of the fragments may occur and nonunion may follow On the other hand, if the sequestrum is allowed to remain inside the involucrum for too long a time, the irritation produced stimulates the laying down of dense sclerosed bone, and a chronic bone cavity results The surgeon in charge of a case of suppurative osteomyelitis, consequently, should carefully select the proper time to perform the operation of sequestrectomy, that time is when sufficient involucrum has formed to support the continuity of the bone, but before the osseous tissue has become hard and ivory like by x ray as a result of the long drawn out suppuration

Sequestrectomy The operation should be performed in a bloodless field With the patient under anesthesia, the involved limb is elevated in order to allow the blood to drain from it, and a tourniquet is applied The skin is then prepared, a flat sandbag is placed beneath the involved bone, and the part is carefully draped with sterile sheets and towels The incision in the skin should be elliptical in shape, so that it includes the scar and the opening of the sinus both of which should be excised It is then deepened to the periosteum, the muscles and other soft structures being pushed aside The cloaca in the involucrum is then sought, and when this is located the periosteum is incised longitudinally so that the incision crosses it The edges of the periosteum are then pushed back with an elevator, exposing the involucrum covering the sequestrum Starting at the mouth of the cloaca the opening can be easily enlarged by using a rongeur, if the osseous tissue has not become too hard and dense Only a sufficiently large enough opening to remove the sequestrum need be made A long sequestrum often can be teased through a very small opening if the involucrum is thin The opening, however, should be large enough so that the cavity in which the sequestrum lies can be thoroughly explored, in order that all the dead bone may be found and removed The surfaces of the walls of the cavity are then gently curetted and wiped with dry gauze, so that all loose fragments of tissue will be removed If the circulation of the new bone is sufficient, the roof of the cavity and overlying edges need not be entirely removed, as granulation tissue will eventually grow out and fill it

Saucerization If the disease is long standing and the involucrum is made up of thick, dense, sclerotic bone, a different procedure should be followed. A much larger

amount of overlying involucrum will have to be cut away by chisel or gouge than in those cases in which the bone is more newly formed and soft After the cavity has been exposed, its entire roof must be excised so that it will finally have the form of the inner surface of a shallow teacup or saucer This requires that all the overlying edges be cut away and smoothed off, and all sharp spicules and septums within the cavity destroyed Particular care must be used by the surgeon to see that no recesses and no sinuses leading to other cavities are overlooked Failures in operations of this kind are most often due to lack of sufficient thoroughness on the part of the operator in exposing and widely opening all the cavities within the involucrum These bone cavities, though they may sometimes contain sequestra, are often empty, and fail to close only because there is not sufficient circulation in their dense walls to allow the granulation tissue lining them to grow out and heal them up By means of this operative procedure the cavity is obliterated, and a compensatory circulation is supplied If the procedure is carried out properly the surrounding soft tissues will drop into what remains of the cavity and its bony walls will obtain a new blood supply from this tissue

After care Having carried out either one of these procedures vaselined gauze is then lightly packed in what remains of the bone cavity and the wound so that the edges of the wound in the soft tissues are held widely apart The part is then dressed with a large amount of dry sterile gauze, which may be held in place with a bandage, and the tourniquet is removed The limb is then completely immobilized in a plaster encasement

The plaster is applied over a padding of cotton batting The encasement should be extensive enough to prevent motion at either of the adjacent joints On no account should a window be cut in the encasement for inspection or dressing of the wound When a dressing of the wound becomes necessary, on account of soiling of the plaster or odor from the discharge, it should be done under the strictest aseptic precautions, so as to prevent contamination of the wound by some secondary organism The encasement may be bivalved in the ward before the dressing, but it should not be removed until all is ready and the patient has been taken to the dressing room The procedure to be used has been already described under the treatment of acute osteomyelitis

The operative procedure for both acute and chronic osteomyelitis, as described, follows the technic as laid down by H Winnett Orr, with but one exception After curetting the cavity in the involucrum during sequestrectomy for chronic osteomyelitis, Orr recommends that its interior be wiped out with a 10 per cent solution of iodine followed by alcohol We see no advantage in this, and believe that it may do some harm

Much has been written of the use of maggots in clearing out the cavities in bone, after the sequestra have been removed[8] or after the bone is saucerized This method is not being used, however, as much as formerly, for most surgeons with experience have come to the conclusion that, with proper understanding of the lesion and a carefully planned technic, better results will be obtained by the methods here described It should be remembered that, if success is to be attained by these methods not only must all necrotic tissue be removed, but a blood supply must be obtained from normal tissue for the bone and that much of the soft parts are so infiltrated with scar tissue that they lack sufficient circulation to heal properly [In very young children showing extensive involvement of radius, ulna, fibula, or clavicle, extensive subperiosteal resection may be done with reasonable assurance of adequate regeneration provided length and axis are maintained in the extremity involved, in the first three instances cited by adequate plaster immobilization until regeneration is complete This is advisable

only up to *four* or five years of age at the most, and when the lesion is extensive and remains active despite chemotherapy and surgical drainage as advised in this chapter It is rarely indicated It is inadvisable in femurs, humeri, and tibiae

In the adult, resection can be done in clavicle, fibular and scapular cases, and in carpal, tarsal, metacarpal and metatarsal cases when they are persistent and extensive

While there are still some adherents to the *Carrell Dakin method of treatment* in both the acute and chronic types of osteomyelitis, it has been largely abandoned It can be quite effective, but it requires meticulous attention to detail, is time consuming and the frequent dressings are apt to be extremely upsetting to the young patient

The *introduction of chemotherapy*, including the use of penicillin, locally and systemically has opened up a new field of possibilities in the treatment of chronic osteomyelitis

It must be considered however, to be as yet in the clinical experimental field, and it is entirely too early to advise the use of many of the procedures advocated in the literature Chronic osteomyelitis is subject to such marked variations in regard to periods of quiescence and flare ups varying *from months to years* that *a little caution* should be exercised in wholeheartedly espousing a method of treatment because it has apparently 'cured' a chronic osteomyelitis as decided after a year or so of observation The potentialities of the situation, and some of the applications made are discussed *in the section on chemotherapy*, Chapter 22 —Ed]

SCARS ADHERENT TO BONE

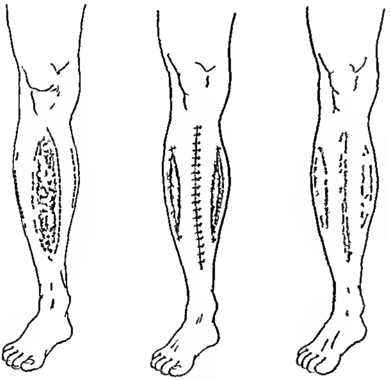
After operation for osteomyelitis of the tibia, the scar may become densely adherent to the underlying bone This can occur in other bones, but is more frequent over the tibia because of the superficial position of its shaft A broad scar is usually present, closely adherent to the anteromesial surface of the diaphysis of the tibia The skin forming this scar is composed only of epidermis, and it lies directly upon the periosteum As there is no corium or subcutaneous areolar tissue, this epithelial layer is entirely dependent for its nutrition upon the vessels of the bone cortex Since the bone is usually sclerotic, the circulation is poor In consequence of the adherence and poor nutrition of this scar slight accidents may cause injury to the epidermis and ulceration *frequently follows*

This condition can be corrected usually by the excision of the scar and by drawing the edges of the wound, which is now composed of normal skin with areolar subcutaneous tissue together over the surface of the tibia

The operation *should not be performed* until some six months or a year after the osteomyelitis has completely healed Following induction of anesthesia, a bloodless field is prepared by using an Esmarch bandage The normal skin close to the circumference of the scar is first incised (Fig 406 A), then the epidermis of the scar with the underlying periosteum can be easily separated from the surface of the bone by a flat edged elevator If the cortex is much thickened and eburnated some of the excess *bone may be removed* with a sharp chisel and the surface smoothed off with a rasp, this will make the contour of the bone appear more normal The skin and subcutaneous areolar tissue are then undermined on each side of the wound, separating them from the fascia covering the muscles This *must be done* for some distance to each side so as to freely mobilize the flaps in order that the edges of the wound may be approximated without tension The removal of the exuberant sclerosed bone from the shaft of the tibia will *often* make the approximation of the edges easier If the edges cannot be approximated *even then without tension*, relaxing incisions must be made (Fig 406 B) These incisions, about two thirds the

length of the wound that is to be closed, are made parallel with and from two to three inches on each side of it This makes two double pedicle flaps which can be slid together easily over the bone surface In every case complete hemostasis must have been effected before closure is undertaken The wound is closed in layers, first the areolar tissue is brought together with interrupted stitches of plain catgut and then the skin edges are carefully apposed with interrupted sutures of silk If relaxing incisions have been made, the edges of the skin at the angles of these wounds may be apposed provided they can be brought together without tension The area which remains open in these auxiliary wounds should be covered with an Ollier-Thiersch or split-skin grafts As the grafting is done on the surface of a wound in the soft tissues, healing readily takes place and the resulting scar is soft and pliable (Fig 406 C) The part is then dressed with dry sterile gauze and the leg and lower thigh are covered generously with cotton batting, which is snugly covered by a flannel bandage exerting firm pressure A plaster encasement is applied from the toes to the upper third of the thigh The encasement should be taken off at the end of 12 days or two weeks, at which time the sutures are also removed.

[The part must be kept moderately elevated during the whole time of healing, and following the removal of the plaster encasement and the sutures, dependency of the extremity must be resumed gradually Elastic support by bandage or stocking for a



A B C

FIG 406

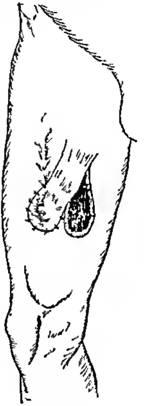


FIG 407

FIG 406 Plastic repair by releasing incisions
FIG 407 Plastic repair by direct swing of flap

while is a help in maintaining adequate circulation —Ed]

A depressed scar on a muscular portion of the limb will often prevent healing if the edges of the skin become attached to the surface of the deep-seated bone Such a condition may be treated by raising a pedunculated flap, either laterally or mesially to the dimple in the skin The flap may then be shifted over to fill the gap after the left humerus He had had these conditions since childhood, when he had contracted an acute osteomyelitis of the tibia From time to time since then these lesions had become active

On the left leg, covering the entire subcutaneous aspect of the tibia was a long, broad scar which was densely adherent to the underlying bone The skin was merely epithelium firmly fixed to the osseous tissue At the upper angle of this scar there was a cavity which extended for some distance into the

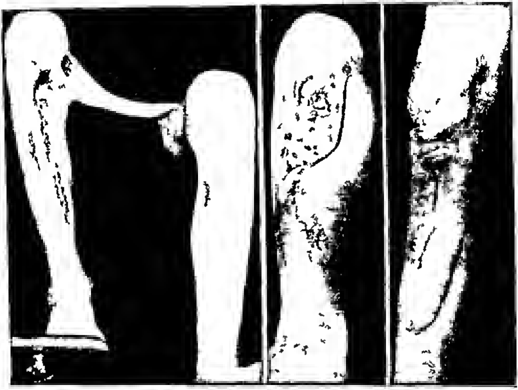


Fig 408 Pedicle graft for chronic osteomyelitis (Courtesy, Surg Clin N Amer, 17 188 189)

invaginated scar has been excised (Fig 407)

Other means may sometimes have to be used to correct this condition when there is not sufficient normal skin to slide over to fill the gap occasioned by the excision of the scar The history of such a case is presented as an example

G W, a man aged 35 years was admitted to Bellevue Hospital on January 31 1933, with a diagnosis *of chronic osteomyelitis of* the left tibia and fibula and of the right and cancellous bone of the metaphysis of the tibia Much of this cavity was unlined with skin, and carious bone was exposed

During his first admission the chronic osteomyelitis of the right humerus was treated

On December 2, 1933, the patient was readmitted, complaining of ulceration of his right leg It was evident that he would continue to have trouble with this leg unless the scar over the tibia could be made soft and pliable and the cavity in the cancellous bone of the metaphysis healed As there was not sufficient skin on the leg to slide over the tibia

from either side, it was decided that skin and underlying subcutaneous fat should be brought from some more distant place Therefore, early in January, 1934, he was operated upon

A double pedicle flap was raised from the left side of the abdomen, just above and parallel to Poupart's ligament and the crest of the ilium This flap was tubed and the skin edges were closed beneath it On May 9, 1934, the upper and outer pedicle of the tube flap was cut across swung downward, and its edge sutured into an incision which was made on the anterior surface of the left thigh It was allowed to remain in this position until August, when the lower and innermost of the original pedicles which was attached to the abdomen was divided and this end of the tube flap was brought down and sutured into an incision on the anterior mesial surface of the upper part of the left leg (Fig 408, *left*)

On October 5 1934, that pedicle which was still attached to the thigh was divided, and the tube after being partly opened at its distal extremity, was spread out over an area from which the lower third of the cicatrix attached to the tibia had been excised (Fig 408 *center*) Finally, on December 3, 1934, the remaining portion of the cicatrix was excised and the cavity in the upper end of the tibia having been curetted, the remaining part of the tube was opened and carefully placed so that the entire area from which the cicatrix has been excised was covered with normal skin and subcutaneous tissue and the cavity in the upper metaphysis of the tibia was lined with the same tissue The edges of the flap were carefully sutured to normal skin at the edges of the wound and several small drains were inserted (Fig 408, *right*)

The edges of the flap healed kindly and the patient was discharged from the hospital on February 2, 1935, with a healed and useful leg Since then the patient has been able to walk and move about in a normal manner When last seen, in April, 1940, the patient had had no more trouble since this procedure was carried out [9]

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17

Miscellaneous Bone Disease and Infection

CLAY RAY MURRAY, M D

OSTEITIS CYSTICA FIBROSA

Two types of this disease are recognized—(1) the generalized form and (2) the local bone cyst

The Generalized Form This is associated with parathyroid tumor and hyper activity and is treated by the removal of the parathyroids with postoperative calcium therapy to prevent tetany The skeletal lesions are often extreme, and multiple fractures are common The author has seen a three inch section of the tibia, in a severe case with multiple fractures which had become so completely cystic that it was actually fluctuant and was represented in x ray by a three-inch gap in the tibia Marked decalcification of the noncystic portions of the bones occurs The cystic lesions should not be subjected to surgery in these cases, but the safeguarding of the patient against fracture and the treatment of the fractures, which occur so frequently, constitute a major problem in treatment

The patient noted above had bilateral subtrochanteric femoral fractures, a supracondylar femoral fracture, a fracture of one tibia and cystic solution of continuity in the other, a fracture of one humerus, and one of the opposite radial shaft in addition to some rib fractures Despite bilateral balanced suspension with traction to both lower extremities postoperatively, she sustained a refracture of one femur, and another radial fracture

Preoperatively, circular plaster can be used to protect fractured members

Postoperatively these patients put on a great deal of weight, largely by fluid replacement, and develop edema during the early postoperative stage This occurs so rapidly postoperatively in the cases which have been badly dehydrated that a satisfactory preoperative plaster may become daogerously tight, and some form of traction suspension may be necessary in the lower extremity The complicated cases frequently require the exercise of considerable ingenuity in the use of the conservative measures of fracture treatment Their healing time is slow

The Solitary Bone Cyst This varies considerably in its pathology Microscopically it may be identical with the giant-cell tumor, and the differentiation is frequently made on the location of the lesion If it lies in the epiphyseal end of the bone, it is called a giant cell tumor, if it lies in the diaphyseal portion of the bone, it is called a bone cyst It is here considered as a lesion of the diaphysis

TREATMENT The treatment is decortication of one face of the cystic cavity, thorough removal by curettage of the contents (or of the lining if no solid contents are found), cauterization of the whole inside of the cavity with carbolic followed by alcohol, packing of the cavity with bone chips from healthy bone (preferably cancellous), and primary closure and pressure dressing Local

recurrence is apt to follow incomplete procedures, and the greater the number of giant cells present the more apt there is to be recurrence. Removal is adequate only when healthy bone or marrow tissue is reached. If the cyst is large, postoperative protection by splint is desirable.

The prevalent idea that a fracture through one of these cysts results in cure is erroneous. Only about 18 per cent of the cysts through which fracture occurs resolve as a result of the injury. The remainder seem to increase in size after injury. (See also Chapter 12 on Bone Tumors.)

VON RECKLINGHAUSEN'S DISEASE

Von Recklinghausen's disease, characterized by the occurrence of multiple neurofibromata along the course of the cutaneous nerves and multiple cystic changes in the long bones with osteomalacic softening, resulting often in secondary deformities and fractures, is subject to no specific treatment. Therapy is confined to the excision of the neurofibromata when feasible, and the correction of the bony deformities by appropriate osteotomies followed by plaster in the corrected position. Bone healing after osteotomy and fracture in these cases is not delayed, as one might suspect, but is average in time and normal in character and is usually adequate, although the new formed callus ultimately is affected by the disease. Because of the character of the bone, manipulative reduction and plaster immobilization are indicated. The use of skeletal traction, the multiple-pin methods, and internal fixation should be resorted to only in the event of failure of the more conservative method to secure adequate reduction.

OSTEOMALACIA

The term osteomalacia is here used to include what is probably a variety of conditions from an etiologic standpoint, all resulting in postadolescent decalcification of bone with a low serum phosphorus and calcium, and a negative calcium balance. They are of interest from two standpoints. A great deal can be done toward the prevention or minimizing of spinal and extremity deformities by the adequate use of braces and supports when the tendency to deformity is recognized early. Patients who would otherwise be bedridden can, by careful adaptation of support to their specific problem, be made ambulatory and capable of looking after themselves. The task frequently requires patience and ingenuity, but it well repays the effort. Deformities already present may sometimes be corrected by the use of corrective braces over a long period of time.

The second point is the treatment of fractures in this group, which are apt to be frequent. Remarkably enough, the healing time of fractures is the normal average or slightly less than that, and the callus, after it is formed, becomes osteomalacic like the rest of the skeleton. Skeletal traction, multiple-pin methods, and internal fixation are not suited to these cases, and manipulative reduction and plaster is the preferred method.

RACHITIS

The surgical treatment of this disease, which is daily becoming rarer, is limited to corrective osteotomies and to the treatment of fractures in conjunction with the treatment of the disease itself by medical means. It would seem that in the active stage of this disease the healing of osteotomies and of fractures is delayed. Once the progress of the disease has been halted, this is not the case. During the active stage of the disease supportive or corrective braces may prevent or correct deformities. When fracture occurs in the presence of deformity it may sometimes be utilized as an osteotomy for correction, but this may be inadvisable because of the line of fracture, and it may be wiser to add an adequate osteotomy, or to secure healing in the posi

tion of the original deformity, reserving proper osteotomy for a later date Operative procedures on these cases are best reserved for the time when the disease itself is controlled [See Chapter 5]

OSTEOGENESIS IMPERFECTA (FRAGILITAS OSSIUM)

There are three forms of this disease —(1) the congenital, (2) the infantile, and (3) osteogenesis imperfecta tarda—all characterized by blue sclerae, and differing only in their severity and the time of the appearance of symptoms

Congenital Form The congenital form is the most severe and the most frequent Most of the cases result in death before birth The rest have fractures at or shortly after birth The head is small and the bones are soft The bones by x ray are rarefied, with a thin cortex, and other healed fractures are usually found The epiphyses are normal in appearance The bones are characteristically pipestem in structure The prognosis for the congenital case born alive is poor, and the nursing handling is of the utmost importance in minimizing the chances of additional fractures The treatment of the individual lesions is by the methods described for birth fractures [See Chapter 43]

Infantile Form The infantile type may affect children of normal gross appearance, except for the sclerae, and may not be recognized until the child begins to walk and become active, when fractures occur with minimal trauma or spontaneously The x ray appearance of the bones is characteristic No growth disturbance is present unless an epiphysis is involved in an individual fracture The lesions heal normally, and the treatment is the usual one for the individual fractures Most of these cases seem to lose their tendency to frequent fracture when adolescence is past, although the bones still retain much of their characteristic appearance

Osteogenesis Imperfecta Tarda. This appears in later youth, and rarely after adolescence The picture is identical with the other two types, and the therapy for the fracture is routine It would seem that these later cases are more apt to carry the tendency to fracture into and sometimes through adult life

In addition to the treatment of the fractures which occur, various corrective osteotomies may be necessary for deformity occasioned by malunion of fractures and by epiphyseal growth disturbances secondary to fracture

For the disease itself there is no known effective therapy

OSTEITIS DEFORMANS (PAGET'S DISEASE)

For the disease itself there is no therapy which is effective For the pain associated with it, deep x ray therapy to the painful region is frequently very efficacious

Fractures occurring in Paget's disease are of two types That which corresponds to the fracture in the ordinary individual is, in the Paget's case, characterized by a peculiar axe-chop appearance, with smooth edges to the fracture surfaces, and with a tendency to a step-cut type of fracture line The smoothness of the fractured cortical surfaces, and the sharply angular step-cut conformity of the fragment ends, often makes retention of the corrected position difficult Multiple pin methods or open reduction and fixation are frequently indicated in these cases [See Chapter 22] With adequate reduction and fixation the healing of the fracture is not prolonged beyond the average for normal bone, although the healing ultimately becomes affected by the disease

The second type of fracture seen is that of multiple cortical cracks, as though a very thin osteotome had been driven into the cortex These are associated with pain and local soreness They are most common in the tibia, but may occur in other bones When Paget's is associated with pain, it is wise to make sure by x ray that this lesion

is not the cause before using deep x ray therapy When these cortical fractures are found, rest by splinting is all that is indicated until all pain and acute local tenderness have disappeared

SCLEROSING OSTEOMYELITIS OF GARRE

This disease, characterized by a chronic dense sclerosis and thickening of a long bone shaft accompanied by pain and tenderness, but usually without fever or blood count, is supposed to be a low grade infection Cultures from the bone have been uniformly negative, however Occasionally it is confused with the denser forms of osteogenic sarcoma or with the osteitis of syphilis It attacks the tibia most frequently, although any long bone may be affected There is no suppuration and no bone destruction

X ray therapy has been said by some to be a successful form of treatment Others consider it valueless Certainly it has not been outstandingly successful

The boring of multiple drill holes into the affected bone has relieved some cases

Extensive saucerization with collapse of adjacent muscle bellies into the saucer is said to have relieved some cases, with or without the drilling of multiple holes through the bone left behind

In using an osteotome or a gouge on this bone it is well to remember that it is extremely dense, and tends to laminate off in large blocks, somewhat similar to the bone in Paget's disease, and that care must be taken not to produce a fracture in the course of the saucerization Primary closure, pressure dressing, and splinting are indicated postoperatively

TYPHOID OSTEOMYELITIS

Typhoid has become so rare a disease that this condition is now seldom seen It occurs in two forms Its acute form is seen during the course of the disease and produces the symptoms of a subacute osteomyelitis It rarely leads to suppuration and usually subsides with the disease Rest and symptomatic treatment are all that are needed

The occasional case will go on to the formation of a localized abscess This is indolent in nature The edges of the cavity are rounded and even a little scalloped, and there is little reaction in the bone about it The symptoms are mild Its progress is so slow that it is frequently not discovered until a long time after the patient is well A recent case seen by the author gave symptoms enough to warrant seeking medical advice four years after typhoid It was in the subtrochanteric femoral region and showed by x ray as a cavity two and one half inches by two and one half inches, without expansion of the bone but with some thinning of the cortex Sarcoma was suspected as a possibility until a typhoid history was secured The organism was recovered from the pus

The treatment indicated in these cases is saucerization of the cavity, cauterization, and primary closure with a pressure dressing if possible If not, packing and gradual healing by granulation is indicated

SYPHILIS OF BONE

Syphilis of bone may occur in the form of a periostitis, leading to the so called saber shin when it affects the tibia, as a dense sclerosing form of osteitis, in a combination of osteolytic and osteogenic activities which may closely resemble low grade chronic suppurative osteomyelitis or osteitis cystica fibrosa of the generalized form, or as a gumma which may be mistaken for bone tumor, particularly sarcoma It is to be remembered that these are tertiary lesions, and the Wassermann or Klein may be negative Other evidences of syphilis, a provocative Wassermann, and a therapeutic test or a biopsy may be needed to make the diagnosis It is to be kept in mind that, although the differentiation of tuberculosis of bone as a destructive lesion and syphilis as a productive lesion is common, these characteristics are not infrequently reversed.

The disease is, in general, much less frequent than it used to be

The diagnosis calls for antiluetic treatment Surgery is reserved for those cases where extensive destruction of bone has occurred before the diagnosis has been made

While delayed and nonunion in fractures have frequently been ascribed to the concomitant existence of systemic lues, this is not the case unless central nervous system lues with trophic disturbances is present, or unless the fracture is through the site of a luetic lesion in the bone involved

ACTINOMYCOSIS OF BONE

Caused by the ray fungus, derived from cattle, this disease affects the jaws and the spine primarily but may be found in other bones The bone is always secondarily involved The jaws become involved through primary gum involvement, the vertebrae probably through primary gastro intestinal involvement, and other bones by primary skin involvement

It is characterized by severe pain and by the presence of multiple lumpy swellings which are composed of a central pus pocket surrounded by dense fibrous tissue The pus contains sulfur yellow granules which are characteristic Sinuses may form in the indolent painful swellings, and the pus with its sulfur yellow granules may discharge Multiple sinuses are frequent when the skin is involved

Cauterization and packing after complete and meticulous excision of all pathologic tissue plus massive doses of potassium iodide are the indicated therapeutic measures Meticulous and extensive surgery is often necessary Visceral lesions often exist which make any surgical attack on bone purely palliative If no visceral lesions are present, and complete excision is impossible, the iodide may hold the process arrested In extremity cases in which neither attempted excision nor iodides control the condition, amputation may be considered

COCCIDIOIDAL GRANULOMA

This disease, primarily affecting California and later the Southwest, is due to a mold type of organism that enters through the lungs or the skin, and which involves bone secondarily The skin lesions are small, crusted nodules which later caseate and ulcerate, discharging a creamy pus The lung lesions resemble tuberculosis The predominant cell is, however, a polymorphonuclear leukocyte and giant cells contain the spherical shaped nonnucleated oidium The bone lesions resemble tuberculosis The skin lesions, the lung lesions and the finding of the organism in the sputum or in the pus are the factors in diagnosis

The prognosis is poor because of the generalized infection Iodides are not of any use, and radiotherapy is palliative but not curative Early wide resection or amputation is the only hope This is difficult or impossible when the vertebrae are involved

BLASTOMYCOSIS

This infection is much like the preceding The pathology and the portals of entry are the same The organism is found in the sputum and in giant cells in the lesions The resemblance to tuberculosis is similar to that in coccidioidal disease

The treatment of the local lesion is the same as in that disease, plus potassium iodide in massive doses In early cases this may be curative General supportive measures are of course used The prognosis in general is poor

ECHINOCOCCUS DISEASE

This occasionally affects bone in the form of multiple cysts visible by x ray. These may become large and break through the cortex of the bone Scolices and hooklets are not common, as in the cysts in the liver, so that diagnosis may be missed on aspiration There is little or no pain unless a secondary infection occurs The blood picture, stool findings, and other evidence of the disease may make the diagnosis, otherwise

exploration, or a pathologic fracture leading to biopsy, may be the means of diagnosis The frequency of infection in other organs makes the prognosis in the treatment of the bone lesion questionable Early and limited cases can be cured by resection Later and more extensive cases require amputation Local recurrence is common after inadequate resection The vertebrae are among the bones involved and adequate removal of the foci here may be difficult or impossible

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18

Nontraumatic Affections of Epiphyses

RALPH K GHORMLEY, M D

EPIPHYSEAL SLIPPING (SLIPPED EPIPHYSES EPIPHYSIOLYSIS ADOLESCENT COXA VARA COXA ANTEVERTA ETC)

The treatment of epiphyseal slipping is still more or less a matter of controversy many types of treatment have been suggested none of which has been accepted by all those interested in these conditions A survey of the literature leads one to a state of confusion and it must be said that a surgeon s personal experience with the various types of treatment probably has more to do with his viewpoint in selecting types of treatment than in almost any other condition in orthopedic surgery

The reason for the existing confusion regarding treatment is in great part that there are at least four stages through which a case of epiphyseal slipping passes each demanding a different type of treatment Overlapping of these stages leads to variations of the clinical pictures and only adds to the confusion In general there may be said to be fairly widespread agreement as to the stages themselves which are as follows (1) Preslipping stage (2) stage of acute slipping (3) stage of chronic slipping and (4) late stage

PRESLIPPING STAGE

There is considerable disagreement as to just what is meant by this term Some claim that there is a recognizable stage before any actual slipping is present Many others feel that what is called a preslipping stage is in fact a stage of slight slipping the earliest evidence being slight widening of the epiphyseal line from the anteroposterior view and slight displacement from the lateral view often observed only on comparison of the affected hip with the normal hip by means of roentgenograms taken with the hip in identical positions

In many of these cases protection against further slipping can be afforded by prevention of weight bearing on the affected hip The use of crutches and a high soled shoe worn on the foot of the unaffected leg and absolute prevention of weight bearing on the affected leg are often sufficient The situation must be emphasized to parents and patients alike and the utmost cooperation demanded If cooperation is lax the physician can prescribe for use on the affected leg some sort of brace or splint such as a walking ring caliper splint or a Taylor hip splint Other types of splints can be used according to the choice of the surgeon provided the weight is borne on the ischium and weight bearing on the joint and femoral neck is prevented

Such a program must be carried on for a period of months and roentgenographic examination to determine the amount of union between the epiphysis and the neck must be made Once union is fairly well established weight bearing may be commenced gradually Careful periodic exami

nation to determine the degree of union must be made Once union between the epiphysis and neck is established further danger of slipping is past Until such union is demonstrable however one cannot be assured of satisfactory end results

Recumbency in bed for a long period, with traction applied may be used in these cases although it is hardly necessary in most instances Some writers recommend such treatment however and insist that it is necessary My associates and I have found that only in the occasional case of simultaneous bilateral slipping would this be indicated In these cases we would hardly favor it over the operative treatment to be described later Plaster encasements used in these cases can be helpful, but when worn over the length of time necessary to secure union between the epiphysis and femoral neck they may cause a considerable amount of disuse atrophy and joint fixation, both of which are detrimental and unnecessary except in the most unusual case

Operative treatment has been recommended with the arguments for operation based on two premises as follows (1) By various types of operation closure of the epiphyseal line is hastened (2) internal fixation by means of a metal nail prevents and insures against further slipping and prevents deformity

Kleinberg and Buchman have recommended resection of the epiphyseal plate Ferguson and Howorth have advised drilling the epiphyseal plate through an open incision in this way stimulating the process of closure of the epiphyseal line In these cases in which the condition is in the pre slipping stage Wilson [7] has advocated employment of a Smith Petersen nail, introduced by the method of Westcott.

Other methods of treatment have been advocated such as impaction by the Cotton mallet as recommended by Jahss This has not been widely used although others have reported on its use

From these outlined types of treatment my associates and I feel that the more conservative method of nonweight bearing may be safely tried in most cases. There is, however, one type of condition wherein this cannot be used namely, simultaneous or nearly simultaneous slipping of the epiphyses on both sides These cases are not of frequent occurrence but one must be on the watch for them in all cases of single slipping and prevent if possible, bilateral slipping from occurring If this condition seems certain to develop we feel that the method of nailing as described by Wilson should be applied to both hips The technic of nailing is in no way different from that used in treatment of fractures of the femoral neck [For technic see Chapter 35 —Ed]

Stage of Acute Slipping

By this term is meant the relatively rare condition in which the epiphysis has become nearly or totally separated from the femoral neck by acute slipping In this condition, reduction can be accomplished by manipulation [1,5] Any manipulative treatment, however, must be of the gentlest sort Usually, for this procedure, the patient is anesthetized and is supine With the knee and hip flexed to an angle of 45° on the affected side the thigh is rotated gently inward If the rotation is accomplished easily one may be able to demonstrate reduction roentgenographically If reduction is accomplished a plaster spica should be applied The plaster should extend from the costal margin to the toes on the affected side with the foot and thigh internally rotated from 20 to 30° The spica should extend from the costal margin to the knee on the unaffected side. Moderate abduction of the affected thigh should be maintained in plaster

If however reduction is not accomplished by *gentle* manipulation one should *not* proceed with more *forceful* manipulation but should abandon manipulation altogether because any degree of forceful treatment is likely not only to cause damage to the epiphysis and epiphyseal line, but to the

surfaces of the joint as well It is the use of forceful manipulation in improperly selected cases that has brought this procedure into such wide disrepute, whereas it has a real field of usefulness particularly in the presence of acute slipping

If manipulation fails I feel that open reduction of the slipped epiphysis is indicated In opening the joint the epiphysis is found to be completely separated and practically free of the neck although it may be held by a few strands of periosteum usually at the posterior and inferior margins

After the joint has been exposed usually by means of the Smith Petersen type of incision (Figs 409 and 410) the separated epiphyseal portion of the femur is levered into its normal position This is best accomplished by inserting an instrument between the epiphysis and the end of the femoral neck (Fig 411) By using a flat instrument or skid one can slowly and gently rotate the thigh and foot inward until the

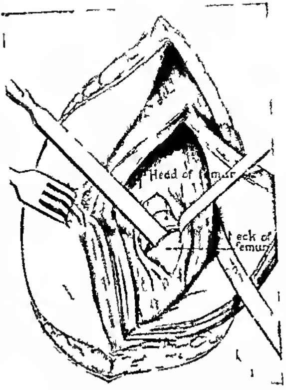

FIG 410 Deeper exposure muscles are reflected from wall of ilium, and epiphysis and epiphyseal line are exposed through capsule

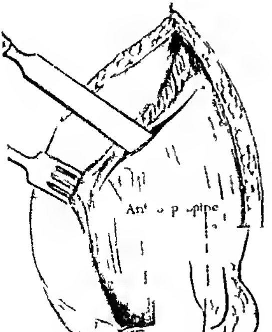

FIG 409 Incision (in insert) and type of reflexion from iliac crest

head is in position Again, gentleness must be emphasized in handling these tissues They are extremely vulnerable and any undue trauma may produce an unsatisfactory end result With careful reduction the decision must be made as to the use of internal fixation Some advocate this and others do not Wilson [1] has been the foremost advocate of the nailing procedure, and has reported excellent results Others have found difficulty in using internal fixation, the epiphysis failing to hold in some cases and a marked tendency to late changes in the epiphysis developing in others this change is attributed to damage, possibly by the nail It is certainly true that in most cases these structures can be held accurately without slipping in properly applied plaster of paris For this reason, many doubt the importance of internal fixation and depend entirely on fixation by plaster Such treatment must be carried out for two to three

months, during which time the epiphysis may become sufficiently united to permit removal of the plaster Motion is gradually restored by exercises, but weight bearing is delayed until apparently complete closure of the epiphyseal line can be demonstrated roentgenographically

STAGE OF CHRONIC SLIPPING

This condition never is treated by manipulation Although the epiphysis may have

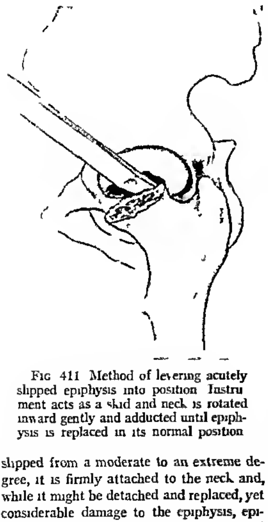

FIG 411 Method of levering acutely slipped epiphysis into position Instrument acts as a skid and neck is rotated inward gently and adducted until epiphysis is replaced in its normal position

slipped from a moderate to an extreme degree, it is firmly attached to the neck and, while it might be detached and replaced, yet considerable damage to the epiphysis, epiphyseal line, and articular surfaces would be done by manipulation sufficiently forceful to accomplish replacement Several authors, particularly in England,[15 19 20] have advocated various methods of traction. We have not had sufficient experience with this type of treatment, perhaps, either to condemn or commend it However, we have used it to some extent but we have been unable to convince ourselves of its effectiveness

It seems to us that an open operation must be performed to correct the deformity in these cases Some feel that many patients would be better off if untreated This is true in some instances but, with improvement in operative technic and particularly with more care to avoid trauma, we feel that better results are being obtained By effective treatment in the course of adolescence many patients will be spared trouble later in life The late disturbances are even more troublesome than those of adolescence

The main object of operative treatment is restoration of the epiphysis to as nearly a normal position as possible and hastening of the closure of the epiphyseal line To the latter end some advocate, as in the "preslipping" stage, excision of the epiphyseal plate Others advocate loosening of the epiphysis through the epiphyseal line and replacement of the epiphysis in its normal position. However, our experience at the clinic has convinced us that cuneiform osteotomy of the neck of the femur just distal to the epiphyseal line, with correction of the deformity, is the best type of operative treatment in the stage of chronic slipping (Figs 410 and 411) We feel that surgical manipulation by instruments must be minimal to insure the best result, and that can best be accomplished by osteotomy The separation of the epiphysis through the epiphyseal line is bound to be more damaging to the epiphysis and the epiphyseal line than is cuneiform osteotomy just below the epiphyseal line (Fig 412)

The question of the use of internal fixation after osteotomy or replacement of the epiphysis must depend on the surgeon's experience with the method Some strongly advocate its use, the technic must be approximately the same as that of internal

fixation of fractures of the femoral neck Many orthopedic surgeons feel, however, that internal fixation is not necessary After replacement of the epiphysis, or after osteotomy, a plaster-of paris spica, carefully applied with the knee slightly flexed and the thigh in slight internal rotation will prevent slipping will insure closure of the osteotomy line and thus will lead to good healing

Such fixation should be maintained for two or three months and as in cases in which open reduction has been performed for acute slipping exercises are commenced at the end of eight to ten weeks to promote return of motion of the knee and hip Full weight bearing should be prevented until one can demonstrate roentgenographically fairly complete closure of the epiphyseal line

Late Stage

Many patients with slipped epiphysis are seen too late for treatment By too late we usually mean after the epiphyseal line has closed Some patients may appear for examination in late adolescence but most of them will appear in adult life when owing to stresses and strains on the maladjusted joint surfaces and sockets symptoms develop which demand treatment Conservative measures at this stage are of little use except to relieve severe episodes of pain temporarily Pain usually is dependent on activity If the patient can be content to lead an inactive life often walking with crutches and using local heat and massage, he may not experience many symptoms However, most patients are not content to be invalids, and demand treatment Often they are willing to submit to surgical treatment in order to secure relief Such treatment has been shown to have bad varying success Osteotomy, arthrodesis, acetabuloplasty, and arthroplasty are the procedures most often used [12]

Osteotomy This is of value in many cases and is more often recommended in cases which have reached the late stage than any other sort of procedure The most commonly used type of osteotomy in this country is the Schanz osteotomy, elaborated by Pauwels Others in use are the Gant operation, a linear subtrochanteric osteotomy Many other types of osteotomy have been recommended by other authors An excellent summary of the different types of osteotomy can be found in an article by Huc [10] How permanent the results of these operations may be, in so far as relief of pain

Fig 412 Line of cuneiform osteotomy used in restoring position of epiphysis in stage of chronic slipping (After Ghormley, R K, and R D Fairchild Jour Amer Med Asso, 114 229 235)

and other symptoms is concerned, is uncertain, because in many of these cases not enough time has elapsed to allow results to be ascertained [See Chapter 15 for types of osteotomy —Ed]

Arthrodesis While in all probability those patients with the most intractable pain will respond best to arthrodesis, this procedure has its limitations, for it is not adaptable to cases of bilateral slipped epiphyses Many individuals are not satisfied to go through life with an ankylosed hip

and, for this reason, we feel that much effort must be put forth to improve and develop more conservative types of operation [Types of arthodesis of the hip are described in Chapters 7 14, and 15 —Ed]

Acetabuloplasty This procedure was recommended by Smith Petersen[17] in 1936 and has been used considerably since then While it does not produce the ideal result, it is felt that it has a place among operative procedures and may give considerable relief in many cases of painful hip caused by old slipped epiphyses [See Chapter 15 —Ed]

Arthroplasty While most types of arthroplasty have not been popular in treating patients with slipped epiphyses, we feel that the vitallium cup arthroplasty, as described by Smith Petersen,[18] may be of value in some cases It has not as yet had sufficient trial to justify any final conclusions regarding its efficiency [See Chapter 15 —Ed]

LEGG CALVÉ PERTHES DISEASE

Treatment of Legg Calve-Perthes disease is mainly one of protection of the affected epiphysis during the active stage of the process Once the diagnosis has been made, a program of treatment should be outlined to the parents Patients who have acute pain may need more active treatment than others By this we mean that patients exhibiting symptoms of pain and muscular spasm should be put to bed with traction applied until such spasm and pain have subsided If spasm is not severe enough to produce deformity, a plaster spica can be applied and the patient's symptoms relieved in this manner However, such treatment should be maintained only for a temporary period

In all instances it is important to explain to the patient that his condition must be watched and treated for two to four years During this period the head and neck of the femur undergo certain changes, if weight-bearing during this cycle of changes is absolutely prohibited, restoration of the epiphysis to fairly normal size and shape is fairly certain to follow Danforth demonstrated this in a series of patients treated by rest in bed or by use of the wheel chair With cooperative parents much can be accomplished, but the method may be economically impossible in many instances If children cannot be given care in bed during the necessary years, the use of crutches, the wearing of a high soled shoe on the unaffected foot, and absolute prohibition of weight bearing on the affected side will result in apparently good healing with little deformity of the head

From time to time, operative treatment has been recommended, but it has not been widely accepted Bozsan[3] in 1932 recommended drilling from the femoral neck into the epiphysis for this condition, without reporting any end results Ferguson and Howorth,[8] reporting on a similar procedure recommended for use in the early stages, described their operation as follows

> The hip is exposed through a Smith Petersen incision, and the capsule is incised anteriorly The hip is then inspected and specimens of synovial membrane and capsule are taken A small window is cut in the cortex of the femoral neck proximally (the bone and periosteum are retained for the laboratory) Through an opening several holes are drilled with curved awls and curets into the femoral head in various directions The opening is closed with a bit of muscle to prevent bleeding into the joint Careful hemostasis and anatomical closure are made, and a snug adhesive strapping and a flannel spica are applied

In the same article the authors reported the use of this operation in cases of coxa plana (15 hips) They stated that the operation produced the following results

> The repair in the bone began immediately, no new areas of increased density developed the reparative stage was greatly shortened the clinical condition always improved The hip may become perfectly normal clinically and roentgenographically, this result has not been observed in patients who have not been operated upon, except in abortive cases

Further reports from such operative procedures should be forthcoming perhaps it is the best method of treatment It has yet to be widely adopted End results from conservative procedures while not perfect are so satisfactory as to make operation seem unnecessary unless striking results can be obtained

ADOLESCENT ROUND BACK

Acute Phase During the period of onset and the acute phase of this condition the most important point in its treatment is complete rest preferably in bed with a Bradford frame used to insure extension and correction of any deformity The impression that some element of focal infection is responsible for this condition has gained so much ground that removal of foci seems important A period of treatment in the hospital in recumbency on a Bradford frame curved to give hyperextension to the affected portion of the spinal column should accompany the removal of foci of infection The period over which recumbency should be maintained cannot be stated exactly as the time necessary for healing is uncertain In general the practice has been to continue such recumbency until all evidence of muscular spasm has subsided and then to allow the patient to be ambulatory for a few hours each day wearing a Taylor back brace or a corset with heavy steel stays and shoulder straps Such supports should be worn for one or two years During this time the patient should continue active daily exercises which tend to develop the erector spinae group of muscles and to stretch the spinal column the patient lies on a hyperextended frame or on a stiff bed with the back arched over a bolster or pad Moreover periodic physical examinations and repeated roentgenographic examinations should be carried out in order to follow the course of the disease

When the margins of the vertebrae again have become more or less continuous healing is complete There may then be some relaxation in the program of treatment We believe however that examination should be carried out from time to time until late adolescence as neglect may lead to the development of a severe permanent round back deformity and one that may be difficult to treat Plaster jackets can be used instead of braces These should be applied carefully with the patient in hyperextension on an apparatus such as the Goldthwait frame Such treatment precludes the possibility of exercises and other beneficial physical therapy Under circumstances where cooperation of the patient in such measures cannot be assured a plaster jacket may be used as it means a better protection against an increase in these patients deformity

Late Phases During the late phases of the condition either in late adolescence or adult life an occasional patient has severe persistent pain If it can be demonstrated that such pain is of postural cause that is if it is relieved by rest and increased by activity a spinal fusion or bone grafting operation may be performed to fix the affected portion of the spine [The technic of spinal fusion is described in Chapters 6 7 and 14 —Ed]

OSGOOD SCHLATTER DISEASE

This condition usually affects patients in early adolescence and represents an acute strain of the epiphyseal portion of the tibial tubercle secondary to the pull of the patellar tendon attachment to that tubercle

During the acute phase rest is the most important part of treatment An adhesive plaster strapping applied along the anterior surface of the knee crossing at the level of the tubercle and reinforced with semi elastic bandage is usually sufficient to limit flexion so that pain will be prevented and if worn over a period of weeks will permit healing to take place Occasionally it is necessary to reinforce such a dressing with some form of posterior splint to prevent flexion of the knee A circular plaster may be used, but is seldom necessary Because

of atrophy resulting from disuse accompanying such treatment, it is unwise to use prolonged fixation in plaster in cases of this type

The most important part of the treatment is a word of precaution to patient and parent alike against strenuous activity during the acute and subacute stages of the disease Any participation in violent exercise will keep the symptoms active and will lead to a more chronic phase, which may become more troublesome Usually strict precautions against such activity will help in preventing the frequent recurrences which lead to the more chronic stage

In this condition, as in Legg Calve-Perthes disease of the hip, operation has been recommended from time to time Bozsan[4] has described a drilling procedure whereby one or two channels are drilled through the disease area indicated on the roentgenogram, into the cancellous upper end of the tibia He reported that in six cases treated in this manner the clinical symptoms subsided in three or four weeks and that complete bony restoration was demonstrated roentgenographically as early as seven weeks after operation

Bosworth recommended pegging of the epiphysis of the tibial tubercle with autogenous bone pegs in order to obtain the same end He recommended his procedure in cases of long standing As is the case in Legg Calve-Perthes disease, this operation has not been widely used Most patients will recover without disability if the conservative treatment previously outlined is continued for a reasonable period

An occasional case may be encountered in which a portion of the epiphysis apparently becomes detached and later on may appear as a loose body Removal of such loose bodies is indicated when they are causing symptoms Plastic procedures to reduce the size of the tubercle in the late stages of the condition are, in general, not successful and should be undertaken only in cases of marked deformity or after adult life has been reached and all epiphyseal growth has ceased

APOPHYSITIS OF CALCANEUS

As in Osgood Schlatter disease, this condition is largely the result of excessive strain but in the condition under consideration here the strain is exerted on a hypersensitive heel, mild trauma may irritate the apophysis of the calcaneus Most cases are encountered when the patient is in early adolescence, symptoms are relieved by rest Proper shoes with sponge rubber inside heel pads, and limitation of activities, particularly running and jumping, will afford sufficient relief in most cases In some cases symptoms will persist for several months but on careful inquiry it will be found that the program has not been strictly adhered to, particularly that part of it which relates to limitation of activity Operation is practically never indicated

KÖHLER'S DISEASE

This condition of osteochondritis of the tarsal navicular bone is similar in its etiology to those discussed previously Usually support by means of strapping with adhesive plaster and wearing properly built shoes will suffice to relieve the condition The same restriction regarding activity should be followed as in the other conditions An occasional patient may need fixation in a plaster boot for a period of a few weeks to three or four months It is important to remember that tuberculosis may simulate this condition and that occasionally tuberculosis affects this bone

Campbell recommended fusion of the talonavicular and calcaneocuboid joints if persistent, painful, traumatic arthritis exists after subsidence of the acute stage of Kohler's disease. [For technic of these procedures, see Chapters 3 and 7 —Ed]

FREIBERG'S DISEASE

Patients with infraction of the head of the second metatarsal bone usually are

adolescent girls The use of proper shoes with a transverse bar or pad to relieve pressure on the sensitive metatarsal head is the treatment of choice in the acute stages of this disease The same instructions as to activity apply here as in the other forms of osteochondritis Late in the disease a loose body may appear in the joint and its removal is indicated Occasionally the metatarsal head is persistently painful and removal of the head may be recommended Such a procedure must be advised with caution, and should be avoided if possible, as good results are not always obtained

EPIPHYSITIS

There are, in addition to the previously mentioned types of epiphysitis, usually termed osteochondritis, certain types of acute suppurative epiphysitis These are often not easily distinguished from either acute suppurative arthritis of the adjacent joint or from acute osteomyelitis of the adjacent metaphysis Usually the condition is not recognized until it is well established and extension has taken place into the adjacent joint Drainage of the infected joint is the first step in the treatment In some cases drainage of subperiosteal abscesses adjacent to the affected epiphysis may be indicated After drainage is established one must watch for subsequent epiphyseal changes

In some instances in which the upper femoral epiphysis is involved the entire epiphysis may become sequestered and separate In one instance in my experience it migrated after separation along the psoas muscle to the upper lumbar region If complete necrosis of the epiphysis is noted, removal is indicated Care must be taken to avoid pathologic dislocation of the hip If this seems imminent, fixation in a plaster-of-paris spica is indicated, with the hip in abduction and slightly rotated internally until the capsule of the hip joint has contracted sufficiently to prevent dislocation Ankylosis can be prevented but some shortening of bone cannot be avoided in these cases If only slight motion remains and pain is persistent, arthrodesis of the hip is indicated [For technics, see Chapters 7 14 and 15 —Ed] *If partial destruction of the epiphysis or of the epiphyseal line has taken place as a result of infection the patient must be under observation throughout the period of growth of that epiphysis and if possible, the deformity of bone that may result must be prevented Later, osteotomy to correct such deformities should be performed*

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SECTION SIX

AMPUTATIONS

19

Amputations, Disarticulations, and Prostheses

Paul C Colonna, M D

Part 1 General Considerations

Amputations and disarticulations are procedures that should never be undertakeo lightly Every effort always must be made to preserve and conserve even a partially functioning joint The site of amputatioo is a tremendously important decision for the surgeon to make at times and the sites of election will be described later

Meticulous conservatism toward preserving length is of practical importance particularly in the upper extremity for here the finer movements are so constantly in use that no type of prosthesis can very closely approach the value of a normal joint The excellent results obtained by the cineplastic amputation for upper extremities have been described by Dr Kessler in another section (See Chapter 21)

Amputations and disarticulations have been done for centuries but only since the First World War has there been an increasing rapprochement between the surgeon and the limb maker This intensive follow up in the care of the patient by the operating surgeon is of inestimable value to all people concerned It is not sufficient that the surgeon doing this type of work should be familiar only with the operative details involved Many times the problems of the limb-maker will be better appreciated if the surgeon understands and is sympathetic with the difficulties involved in fitting these limbs with prostheses The surgeon, by carefully conserving tissue, may be able to give length to a stump, or just as easily decrease the limb by a few inches either of these procedures may later help with the prosthesis problem

Some amputations are done for purely cosmetic reasons and these are the amputations of choice Amputations of supernumerary fingers and toes are done largely for cosmetic reasons although occasionally these useless members bother the patient in his daily routine activities In the case of a congenital anomaly, such as the absence of one or more bones the surgeon may operate in order that the patient may discard cumbersome and complicated apparatus and thereby permit fitting with an artificial limb closely resembling the normal extremity It is not, however, for cosmetic reasons that the majority of amputations are done

In any amputation the surgeon must constantly keep in mind that the function of the part may be improved by a partial or complete ablation of the limb In cases of chrooic infection such as osteomyelitis the patient may not only be able to be rid of the infected member which is a source of constant danger, but also be may be enabled by the operation to return to his job as a wage earner with his health greatly improved We also amputate in cases of severe crushing injuries in which it is obviously

impossible to expect anything resembling a return of normal function. Another cause for amputation will be found in those congenital and persistent nonunions of the leg which have resisted all attempts at bone grafting, and in the so-called congenital pseudarthrosis of the bones of the leg. In another section of this book amputations for vascular diseases of the extremities will be discussed. Trauma, congenital conditions, infection, malignant growth, or vascular disease make up the great majority of causes for amputation or disarticulation, as can be seen by the following chart. In a general way one should make every effort to retain the affected member and advise amputation only when absolutely necessary.

Cause for Amputation in 70 Cases

	No. of Cases	%
Trauma	20	28.6
Congenital condition	9	12.8
Infection	12	17.1
Malignant growth	16	22.8
Vascular disease	13	18.7
	70	100.0

At times an amputation will have to be done hurriedly in order to save life, but as a rule the surgeon has time to plan the site of amputation or disarticulation and evaluate the problem arising in the individual case. The site of operation and the technic employed may depend somewhat upon the future economic status of the patient. A patient who expects to engage in hard manual labor will be much better off with an end-bearing stump, for this type will withstand better the wear and tear of active vigorous life. On the other hand, an individual engaged in sedentary occupation may be much better off with a stump requiring a type of prosthesis that is completely different.

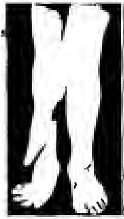


Fig. 413. (*Left*) Bilateral supernumerary little toes.
Fig. 414. (*Center*) Congenital anomaly of right leg and foot necessitating amputation.
Fig. 415. (*Right*) Showing amputation stump of patient shown in Fig. 414 six months after operation.

Too frequently the surgeon has been satisfied if the wound has healed per primam, being unwilling to assume the responsibility of seeing that the individual has an adequate preparation for his prosthesis and of seeing that the patient is fitted with the most satisfactory type of prosthesis possible for his particular problem. Too frequently these casually treated patients are allowed to drift into purchasing an appliance sold by high pressure sales methods that usually proves unsatisfactory.

WHEN TO OPERATE

Conditions Making Operation Necessary

General Considerations The time to amputate or disarticulate may well depend upon the underlying cause for the proce dure In cases of a crushing injury to a part, the limb may be so mutilated that amputation is immediately necessary These injuries are commonly motor or industrial accidents and while crushing of the bone and tearing of the soft parts may be ex tensive these are not in themselves absolute indications

The wound should be carefully and pa tiently cleaned with normal saline solution followed by intelligent debridement if there seems to be any possibility of pre serving in whole or in part the function of the extremity In fresh gunshot wounds am putation is rarely an emergency measure although if there is complete severance of blood vessels and nerves complicating these wounds the operation may be necessary Adequate surgery will often retrieve many apparently hopeless limbs Uncontrollable hemorrhage from the crushed area is a primary factor for deciding upon early am putation

Infections It should be remembered that unless there is an overwhelming infec tion amputation can be reserved for a later date in most of the cases of severe injury With the rapid advance of chemotherapy using sulfanilamide or some of its deriva tives as well as of radiation therapy in the treatment of severe compound fractures amputation will be more rarely resorted to as an immediate procedure When and if it becomes obvious that retention of a severely injured member is hazardous to life one should not delay operation The surgeon should rapidly decide the site of amputation suitable for the individual, as a rule employing the flap method and not the guillotine technic.

In chronic long standing infections in volving part of an extremity, it may be obvious that ablation of the extremity will not only improve the general health, but also will be an economic factor in permitting earlier return to work In *Bacillus welchii* infection amputation is not so frequently resorted to as formerly, for statistical stud ies have shown that few lives are saved by amputation that cannot be salvaged by less radical procedure If however, amputation is decided upon it should be early in the progress of the infection

Gangrene Dry or moist gangrene of a part may follow certain conditions such as diabetes frostbite various types of vascu lar disease such as thrombo angiitis obliter ans arteriosclerosis etc making amputa tion necessary In these gangrene cases it is wise to allow a definite line of demarcation to become established before surgically re moving the part Much tissue will be saved by this method and the choice of site for amputation more satisfactorily determined

Tuberculosis Tuberculosis of the adult joint especially the ankle and tarsal bones complicated by abscess formation and joint destruction will give rise to a permanent loss of function in the joint When the dis ease is so complicated and involves the ankle or foot in the adult amputation in the lower third of the leg is felt to be the treatment of choice This radical type of surgery is rarely necessary in a child suf fering from joint tuberculosis [See Tuber culosis Chapter 14 —Ed]

Crushing Injuries In severe crushing injuries the general condition of the patient may frequently present the more urgent problem In those rare instances in which amputation may be necessary at the scene of disaster, as in accidents caused by the pinning or imprisoning of a member, the amputation may have to be done under conditions far from satisfactory As a rule, however, even emergency amputations or disarticulations can be done in hospital sur roundings

Congenital amputations of a hand or

foot usually need some revision before the application of a prosthesis It is to be stressed that in these congenital amputations of a part there is found more scar tissue and less active muscle tissue than in

Fig 416 Congenital amputation of hands and right foot

amputation stumps following surgery Also, these patients should be fitted with their limb early in order to train them in its use when young

General Rules Regarding Shock

The general condition of the patient should be treated by the accepted methods of treating shock either preceding or during the operation As a rule a low blood pressure and rapid pulse are synonymous with a poor general condition In addition to these signs the volume of the pulse, the temperature and color of the skin, the presence of sweating, combined with the general appearance of the patient, will permit an estimate as to whether or not the patient is in shock These objective signs are of great value

If time permits a more complete investigation concerning any cardiac, renal or pulmonary disturbance should be made in order to arrive at an accurate prognosis for ultimate recovery As a rule, in the presence of a severe injury, the state of the peripheral circulation offers the most reliable index of the general condition of the patient Fundamentally the treatment should be directed toward stimulating the re establishment of the blood flow to the tissues of the body

The actual loss of blood may be through external hemorrhage as well as through the loss of blood or plasma into the traumatized area Dehydration sweating and other loss of body fluids will bring about a reduction of blood volume so that the re-establishment of an adequate volume of circulating blood is most necessary Transfusions of whole blood should therefore be done at the earliest moment and the universal employment of a blood bank permits this treatment to be done earlier than formerly was the case Frequent transfusions of 300 to 500 cc are more effective than the administration of a larger transfusion in one sitting

Next in importance to the transfusion of whole blood comes the administration of blood plasma or serum, saline, or 5 per cent glucose The latter fluids can be forced by mouth or rectum, they are better handled by the body when given intravenously Of course, if there is a suspected paralytic ileus fluids by mouth or rectum are not advisable The character of the pulse is a far more important and reliable index re

garding the patient's condition than is the systolic blood pressure With the constriction of the peripheral arterioles the distribution of the blood is diminished, and while the use of stimulating drugs such as adrenalin temporarily raises the blood pressure, it is done at the expense of the circulation in the peripheral tissues Often, therefore, the administration of drugs may accentuate the condition of shock rather than aid

Manipulation of a badly injured extremity while the patient is in surgical shock is harmful Nerve centers can be most satisfactorily protected by the use of a local anesthetic if an amputation or disarticulation during shock seems advisable Also, in shock, the application of heat to the body in any form is useful, and hot blankets and hot water bottles should be routinely available In addition to the application of warmth to the body, elevation of the foot of the bed and absolute rest, as far as possible, are of prime importance

The problem encountered in traumatic shock, therefore, is essentially due to a reduction of body fluids available in the peripheral tissues and every effort should be made by intravenous medication, or by other means, to fortify the body with adequate fluids, supplying the body with the needed external warmth, and keeping the administration of stimulants at a minimum because of inherent danger (See also Chapter 22)

WHERE TO OPERATE

Sites of Election in Upper and Lower Extremities

Having decided that the conditions requiring amputation or disarticulation have been fulfilled and that the patient is in a satisfactory general condition, the next thing to be decided is the most desirable site for operation As has been mentioned, our decision is based upon the ultimate function to be anticipated The sites of election in the lower extremity can be more clearly defined, for primarily we are there concerned with weight bearing In the upper extremity real advance has been made by the cineplastic amputations which are described elsewhere [See Cineplastic Amputation, Chapter 21 —Ed] As a rule it is more advantageous to preserve length in the

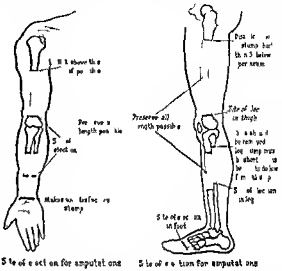


Fig 417 (*Left*) Showing site of election for amputation in upper extremity based upon best functional result to be obtained

Fig 418 (*Right*) Showing site of election for amputation in lower extremity, based upon best functional result to be obtained

upper than in the lower extremity The sites of election of the upper and lower extremities are shown in Figs 417 and 418

Disarticulation at the hip, knee, or ankle is particularly difficult to treat by any form of prosthesis If it seems necessary to disarticulate at the ankle, a far more satisfactory stump for fitting with an artificial limb can be obtained if the amputation is done above the ankle at the middle third of the leg, ordinarily seven inches below the knee is considered the site of election Disarticulation at the knee should not be so heartily condemned as it has been in the past, for a properly fitting prosthesis of the type shown in Fig 419 gives satisfactory control and has the great advantage of not

requiring straps about the shoulder or chest to hold it in place, although a band about the waist may often somewhat control the rotation of the prosthesis As regards the hip joint disarticulation, it is never the method of choice, but occasionally in the case of a malignant bone tumor it may be necessary Following such disarticulation, a

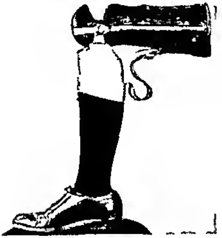


Fig 419 Showing a knee bearing prosthesis which is satisfactory for the end bearing stump following disarticulation at knee

table tilt type of prosthesis is the most practical type and can be a very satisfactory appliance

As a rule disarticulation stumps do not lend themselves to fitting with an artificial limb as well as amputation stumps Careful fitting of an artificial limb that will prove satisfactory for disarticulation stumps is both expensive and difficult Disarticulations should not be entirely condemned, for in certain selected locations, such as the knee, a satisfactory prosthesis can be made In certain cases of malignant bone tumors, disarticulation at the proximal joint of the affected bone seems to delay the course of the disease better than amputation It is justified sometimes even in spite of the acknowledged difficulties of fitting the patient with a satisfactory prosthesis

Future Occupation of Patient

In any consideration of amputation or disarticulation it is of the utmost importance that the future occupation of the patient should be given full consideration If it is not an emergency operation, it is wise carefully to explain to the patient the steps necessary before he can return to his job as a wage earner The judgment of the surgeon will have to decide the most satisfactory site for the particular problem keeping in mind that as far as possible the sites of election as diagrammed should be followed Many times the final decision may rest upon the fact that one patient is to lead an active, vigorous, physical existence and another is to pursue a sedentary occupation

Local Condition

The appearance of the local condition making the amputation necessary will be another factor that will decide the site of election In extensive osteomyelitis of the tibia in which the site of election ordinarily would be the middle third of the leg, it may be necessary to disarticulate at the knee joint or above because of the risk of subsequent residual bone disease There may be marked scarring at the proposed site of operation, or some local skin irritation, or infection, any of these may prove to be the deciding factor Whenever possible we should plan along the lines of certain general principles and rules, but we must be guided by the fact that we are dealing with individuals The advantages and disadvantages of the sites selected must be balanced, but experience has shown the wisdom of adhering to the sites of election as far as possible

HOW TO OPERATE

Technic in General

Flap Method This is the method most commonly employed, and various types of flaps are used The anterior flap as a rule

is longer than the posterior in order that the scar may not be on the end of the stump This type of flap is particularly useful for the weight bearing stump, for if the anterior and posterior flaps are of equal length the scar will be terminal This is not so undesirable in the upper extremity as in the lower The skin flaps should be quite long so that the fascia, muscles and lastly the end of the bone are adequately covered by an even cushion of soft tissue Those inexperienced in amputations will find they are apt to make their skin incisions higher than desirable, frequently falling into the error of making the incision at the level of the anticipated bone end, thereby being forced eventually to divide the bone higher than is necessary If the anterior flap is made approximately the diameter of the limb longer than the posterior, a satisfactory skin closure can usually be obtained the fascia muscles, and bone tissue divided transversely at half inch higher levels, respectively, will permit a conical shaped stump Kirk recommends that stump lengths should be sacrificed to give ideal skin flaps but advises that the suture line be allowed to fall where it will and that available viable skin be later grafted to fill in any gap if necessary

Racket Incisions In the disarticulations there are various types of racket incisions employed This type of incision for the smaller joints and for the hip and shoulder joint is described later in more detail They permit easy access to the joint and allow a satisfactory closure of the wound Here again the tendency is to cut the skin too short or to conserve the muscles insufficiently to form a soft cushion at the site of the disarticulation It must be borne in mind that fascia is inelastic tissue while muscle is elastic, and that ordinarily these structures are fashioned to correspond with the skin flaps so that a snug, but not too tight, closure should be anticipated In sectioning muscles, a conical stump is the ideal to be kept in mind, and not a bulky, squarely shaped mass of muscle tissue which will not fit comfortably within the prosthesis If, therefore, the muscle flaps are trimmed down and antagonistic groups of muscles sutured together over the end of the bone to form a moderately padded stump, the result will be much more satisfactory Certain muscle groups have a greater tendency to contract than others, this is particularly true of adductors of the thigh This must be kept in mind

Use of Histamine Flare Test In cases in which amputations are required in circulatory diseases, the histamine flare test has been found very useful to determine the site of election Histamine hydrochloride 1/1,000 is the substance used in the test The subject is placed facing strong daylight with the extremities bare A wheal ½ cm in diameter is made subcutaneously at the following levels (1) Ankle, (2) mid lower leg (3) just below the knee (4) just above the knee (5) midthigh, (6) opposite limb at same levels (control) Care should be taken to place the wheals in skin which has some underlying subcutaneous tissue, as the skin overlying bone will not give a true response After an interval of five minutes the area of both the wheal and the surrounding flare are outlined with ink and copied on tracing paper to serve as a permanent record The wheal will be small and the flare will vary from ¼ inch to 3 inches or more in diameter, according to the condition of the circulation, using the opposite limb as a control From a comparison of the size of the wheals and flares one may decide the optimum level for amputation

With these circulatory cases the skin flaps and fascia are cut by the flap method and then a circular division of the muscles may be done After dividing the bone the muscles are pulled over the end of it and held by purse string sutures, in these cases the prognosis is poor for handling any type of prosthesis

[See Amputations in Diabetic and Circulatory Cases, Chapter 20 —Ed]

Anesthesia Considerations

Amputations by the early surgeons are reported to have been done in an incredibly short time but it must be remembered most of these were guillotine amputations, no aseptic precautions were taken, and little effort made to carefully control the bleeding except in the larger vessels Infection following the operation was therefore the order of the day Speed of operating is even today a very important factor in this type of surgery, and because many of these patients who come for amputation or disarticulation are poor risks the anesthesia suitable for the individual case must be carefully considered

In those patients without arteriosclerosis or kidney complications, cyclopropane is regarded as the anesthesia of choice Nitrous oxide is not considered satisfactory and certainly the intravenous injection of an anesthetic in the face of a kidney or liver damage is contraindicated

If the patient is a robust, middle aged individual in good general condition, any type of anesthesia may be satisfactory, although we personally prefer cyclopropane or ether The intravenous anesthesia, while eliminated rapidly, has certain dangers There is no fixed dosage with it, although computation can be reasonably arrived at, based on the body weight In the very elderly and the very young it has some risks

Spinal anesthesia with novocaine or procaine if properly handled is a safe anesthetic By using this medium the anesthesia can be so localized that only one of the lower extremities is anesthetized If, however, we are dealing with an apprehensive patient, we feel that spinal anesthesia is distinctly contraindicated because many times these patients are restless and their nervousness will interfere with the operative procedure

Block anesthesia is not considered practical for amputations or disarticulations It requires a good deal of detailed nerve blocking and is unnecessarily tedious for the type of operation proposed

Local anesthesia, 0 5 per cent novocaine with six to eight drops of adrenalin per 100 cc of novocaine, may be employed in amputating a smaller joint if there is any contraindication to general anesthesia It is not, however, recommended in the larger regions of the body, for it requires so much drug that a certain amount of toxicity may ensue

In summary as a rule, cyclopropane is regarded as the most satisfactory anesthetic, as it is a moderately safe and easily controlled anesthetic If it is not available, we prefer an ether anesthetic.

Method of Operation

The limb is prepared as well as the circumstances will permit. A rubber tube type of tourniquet is then applied well above the anticipated site of division of the bone and doubled several times about this level of the limb It is tied so that it will hold firmly and can be removed with ease toward the end of the operation The patient is then draped and the operator must have at hand the usual amputating instruments such as a long bladed knife for severing muscles quickly, one or two small saws, muscle retractor, etc., as shown in Fig 420 If the flap method is used, the anterior flap is made the diameter of the limb longer than the posterior, and the underlying layers of structures must be divided each at a slightly higher level down to and including the bone

With a periosteal elevator the soft tissues about the bone are carefully retracted, being careful not to strip up the periosteum After sawing the bone transversely and at right angles to the extremity but not necessarily at right angles to the bone (which prevents some direct pressure on the stump), care is taken not to roughly retract the muscles away from the bone and produce a periosteal elevation which may later give rise to spur formation Every care is

observed while sawing the bone to prevent splintering or cracking

After dividing the bone and treating the soft tissues as described a cuff of periosteum about one-fourth inch wide is removed from the entire circumference of the bone end and the bone is rounded off with a rasp to remove the sharp corners and irregularities but this technic has proved satisfactory in the majority of instances Some recommend crushing the nerves or using cautery, after which it is severed and allowed to retract Both of these methods have been used in the treatment of the smaller nerves, but for the larger nerve trunks we prefer the alcohol injection method

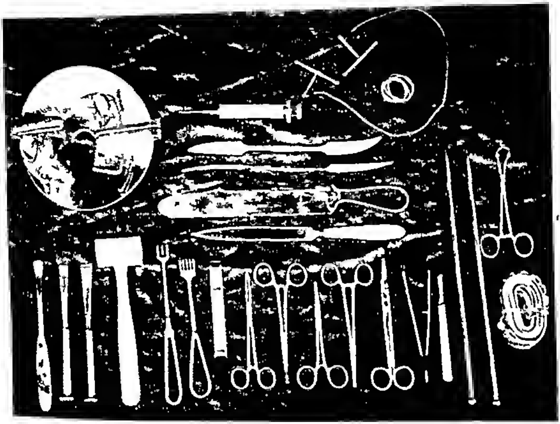


Fig 420 Usual instruments needed for performing amputation

It has been our custom then to identify the larger blood vessels and to apply a double ligature of chromic catgut before allowing them to retract into the tissues

After identifying the nerves, a fine sharp needle is used to inject 95 per cent alcohol into the retracted nerve and its sheath until it is distended in a fusiform manner after which the nerve is cleanly sectioned with a sharp knife distal to the alcohol injection, allowing it to then deeply retract into the tissues No method of treating nerves will completely eradicate the danger of neuroma,

If there is any danger of bleeding from one of the small arteries sometimes accompanying the large nerve trunks, it is better to tie off the nerve with plain or chromic catgut, after which the 95 per cent alcohol is injected within the nerve which is proximal to the applied ligature Kellar has advocated the use of a sharp-pointed cautery which burns a conical cavity in the nerve causing it to further contract and thereby avoid formation of neuroma.

The tourniquet is carefully and cautiously removed by an assistant, taking care

to stop any bleeders or muscle ooze not previously controlled so that one may have as far as possible a dry wound before beginning closure The wound is then thoroughly washed with saline to cleanse it of any small bone spicules or bone dust If at this time the muscles need trimming in order to produce a conical stump this should be done, and then the muscles should be sutured over the bone end The fascia is next closed, taking care to apply a small rubber tube drain transversely in the wound under the fascia The skin is closed loosely with silkworm gut re enforced with silk, and a bandage applied snugly over the dressing about the amputated stump

If the amputation is near a joint, future contraction may be lessened or avoided if a light plaster of paris bandage is applied extending well above the proximal joint, which is held in extension

What Constitutes a Satisfactory Stump?

An ideal stump should be conical and smaller than the opposite side at the same level It should fit into the inverted cone of the prosthesis The soft tissues should not be of sufficient redundancy to interfere with a satisfactory and snug fit, and not tight enough to pull upon the bone end and cause pain through skin tension The scar may be anterior, posterior or terminal depending upon the individual problem, but care should be taken that the skin included in the scar does not become densely adherent to the bone While one should plan on a certain amount of postoperative shrinkage of the soft tissues, the end of the bone should not be covered at closure by more than a one and a half inch thickness of soft parts The aperiosteal method of amputation described by Kirk is the method of choice, and care should be taken that the bone ends are rounded and that there are no sharp edges left to encourage spur formation The nerves should be retracted and injected with 95 per cent alcohol or cauterized to avoid as far as possible the forming of neuroma, and the skin scar should be as soft and pliable as it is possible to obtain

The guillotine amputation is never the method of choice, but is necessary in certain cases following trauma and in the presence of infection The circular guillotine method, which simply consists of a skin incision formed by the knife sweeping in a circular motion around the limb, is a quick method The muscles and blood vessels are cut transversely, the stump allowed to heal by granulation, and a plastic repair is necessary before the stump is ready for prosthesis This was the procedure used extensively by the older surgeons during the antiseptic era, and permitted extremely rapid amputations, the wound was left wide open and healed by secondary intention It makes a most unsatisfactory stump for a prosthesis unless a secondary revision is done, but it entails the least shock to the patient and may be utilized when the time required for a closed amputation entails too much risk.

Part 2 Upper Extremity

GENERAL CONSIDERATIONS

It goes without saying that every effort should be made to avoid any amputation, and this is particularly true in the upper extremity because artificial prostheses, however remarkable they may eventually become, cannot assume the normal function of an extremity

Temporary prostheses are not so essential in the upper extremity as they are in the lower The stump does not have to be developed into a weight bearing one, and it may therefore be fitted early with a permanent prosthesis Until the development of the cineplastic operative procedure with its meticulously mechanized upper extremity,

prostheses were primarily of the single or double hook variety and the patient wore another type of prosthesis for dress or cosmetic purposes In comparison with these

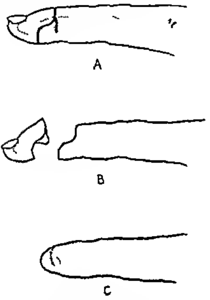


FIG 421 Disarticulation of distal phalanx of finger, assuring satisfactory functional end result

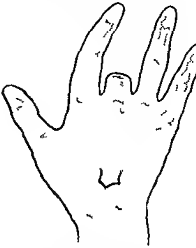


FIG 422 Amputation of finger with short stump A better cosmetic and functional condition results from excision of entire metacarpal bone

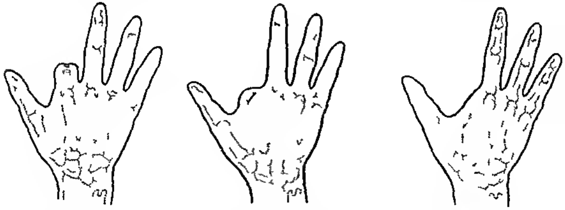


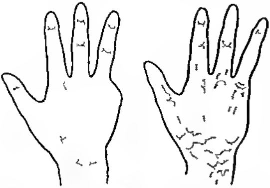
FIG 423 Methods of amputating index finger

artificial limbs offering primarily lifting and gripping movements, the cineplastic prostheses developed by Sauerbruch of Germany, Putti of Italy, and Kessler in the United States offer the finer types of movement and open up a large field of possibilities for increased function [See Cineplastic Amputations, Chapter 21 —Ed]

No blanket rule can be laid down on conservation of tissue, although, of course, one should go high enough through vital tissue in any amputation so that healing will be prompt and movement may be begun early

In contradistinction to the fact that am

putation through any joint of the lower extremity usually is to be condemned, disarticulation *of the distal phalanx of a* finger may result in hardly any handicap



A Poor type amputation B Satisfactory type

FIG 424 Amputation of little finger

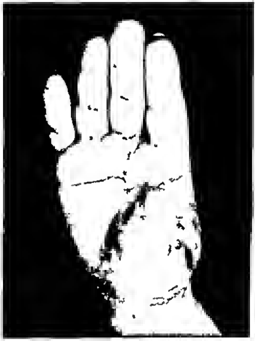


FIG 425 Complete amputation of thumb destroys function of hand approximately 40 per cent

to the patient Amputation of a part of the middle or proximal phalanx of one or more of the fingers results in a short stump, and here a short stump is generally useless It is awkward in appearance and liable to injury In the index finger, if it is necessary to amputate high on the middle phalanx, one would do better to sacrifice the whole finger and a portion of the second metacarpal just above its head, cutting the bone obliquely as shown in Fig 423 The disadvantage in the sharp angulation caused by leaving the bump of the head in any of the metacarpals is obvious, and this type of amputation is recommended only in the presence of an infection when one hesitates to extend the incision to remove a part of the shaft of the bone In the third and fourth fingers while disarticulation at the knuckle joint somewhat preserves the contour of the hand the unsupported metacarpal heads will also have a tendency to move backward and forward when the fist is clenched so that it is better to narrow the hand by removing a part of the metacarpal at operation In the little finger, loss of part or all of the finger constitutes little disability, but when amputation of the entire little finger is necessary it should include the head and part of the shaft of the fifth metacarpal

The most important and valuable member of the hand is the thumb, and it is estimated to be worth almost as much as all the other fingers together Its opposing and grasping action makes it valuable in all types of work, but if all four fingers are lost the remaining thumb is almost useless Therefore, it is most important that a sufficient length of a finger or fingers be preserved if possible, for one has only to recall the uses of the thumb in the countless daily activities to appreciate its function The rule, therefore, is to save as much of the thumb as possible and have it so placed in relation to the opposing fingers that its grasping function can be retained Many times the attitude of the thumb following hand infections is carelessly allowed to become fixed in abduction and on a level with the palm, which gives a practically useless hand

Disarticulation at the wrist does not result in a satisfactory stump for a prosthesis

It is better to amputate three inches above the wrist in order that an artificial hook or hand may be most *efficiently applied* The old Kruckenberg procedure of reconstructing the metacarpals or forearm bones into a two prong *fork* has been *described* by Putti and Kruckenberg and others This technic is less satisfactory than the cineplastic surgery elaborated and perfected more recently This cineplastic method is based upon the fact that the distal and tendinous parts of the muscles remaining can be isolated and enclosed in a covering of skin so that voluntary muscular contraction may be employed The flexor or extensor muscle power can then be utilized by a specially constructed prosthesis bringing about coordinate motions which has been described in detail in another section of this volume It requires mechanical perfection in the prosthesis which is always costly The older method of using a molded leather sleeve for the mechanical hand will always have a limited functional use it is cheap and can be made moderately efficient Most of these prostheses require a control cord running to or around the opposite shoulder so that the movements of the shoulder muscles may be utilized in controlling the major movements for grasping or lifting

DISABILITY EVALUATION

The thumb is said to contribute 40 per cent of the efficiency of the whole hand and the fingers have a respective value of 22 5 per cent for the index 17 5 per cent for the middle, 12 5 per cent for the ring and 7 5 per cent for the little finger The total loss of all the fingers means a total loss of the hand functionally whereas the loss of a thumb and little finger would only be 40 per cent plus 7 5 per cent If the thumb has no finger to oppose its action the hand becomes a totally useless one from a functional standpoint Amputation at the wrist joint is estimated to cause a 90 per cent loss in the functional action of the upper extremity and the loss of the forearm as 95 per cent of the entire upper extremity, while disarticulation at the shoulder joint would represent a 100 per cent loss

Pos type—no oppos on to thumb

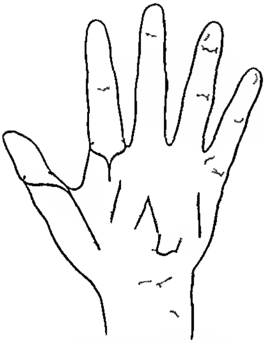
Thumb stump suff c ent for a useful hand

FIG 426 (*Left*) Hand rendered almost useless by this type of amputation
FIG 427 (*Right*) Even a short thumb stump permits some of its grasping action to be retained

FIG 428 An unsatisfactory stump for any type of prosthesis It would be better to amputate three inches above wrist

Unfortunately, there are no fixed awards for amputation of the members of either the upper or lower extremity throughout the United States Different states have definite but different anatomic limitations

and different interpretations Also what constitutes the term band or foot in one locality may not apply in another locality An estimate of disability should therefore be based on the intrinsic loss of function in the part and not upon the amount of function which can be obtained following a properly fitting artificial limb



Amputations in the hand

FIG 429 The best functional result in amputations of hand will be obtained by following above technic as explained in text

OPERATIVE TECHNIC

FINGER AMPUTATION

For disarticulation at the distal interphalangeal joint the end of the digit is grasped with the fingers and the joint is flexed. A transverse incision is made on the dorsum at the level of the joint and the knife passed directly through the articulation The palmar flap is made with the apex toward the end of the finger the tip of the finger being cut through so that the distal phalanx with its nail base is removed leaving a palmar flap sufficiently long to be sutured to the short dorsal flap Before closing the deep flexor tendon and the extensor tendon is sutured to the joint capsule and periosteum just proximal to the head of the second phalanx Interrupted sutures of silkworm gut are used in carefully closing the skin

In amputations through the middle of a finger a palmar flap equal in length to the diameter of the finger at the point of section is made and the flap raised The blood vessels and digital nerves are identified and sectioned The shaft of the bone is then sawed through after which a cuff of the periosteum is cut from the end of the bone The flexor tendons are identified and clamped before division is made They may be stitched to the periosteum or if of sufficient length may be passed over the end of the bone and stitched to the divided extensor tendon The long palmar and short dorsal flap including all subcutaneous tissue are united using silkworm gut or silk for the skin

THUMB AMPUTATION

The method of amputation of the distal phalanx of the thumb is similar to that employed in the finger Amputation through the metacarpophalangeal joint may be done by either the racket incision or a large palmar flap and short dorsal flap The flexor and extensor tendons are sutured to the periosteum If a disarticulation at the interphalangeal joint of the thumb is done the tendons may be sutured together over the end of the proximal phalanx The wound is closed in layers the skin with black silk or silkworm gut

Amputation proximal to the metacarpophalangeal joint should be avoided if it is at all possible for without some stump to the thumb any future reconstructive operation will have small chance of successful outcome

Metacarpophalangeal Amputation

Amputation through the metacarpophalangeal joint of the fingers is best done through a racket incision with a handle on the dorsal aspect as shown in Fig 429 If the incision on the palmar surface is made with a notch as shown therein, it will make a better cosmetic result The incision is carried to the bone and as much of the subcutaneous tissue and soft parts as possible are included in the flaps so that the space over the end of the shaft of the metacarpal may be filled in The flexor tendons are divided and allowed to retract within their sheath The extensor tendon is also allowed to retract after sectioning The head of the metacarpal is removed in the amputation This does not occasion any weakness in the hand and gives a much better appearance If two adjacent fingers are to be amputated excision of the metacarpal head is probably best avoided The removal of the metacarpal head with a portion of the adjacent shaft as shown in Figs 423 424 is particularly helpful when the first or fourth finger has to be amputated The wound is closed in layers, the skin with black silk or silkworm gut

Carpometacarpal joint Disarticulation

A flap type of incision is used with a long palmar flap extending from just below the styloid of the radius down the hand nearly to the middle of the palm and then upward to just below the styloid of the ulna The dorsal incision is made straight or slightly concave across the dorsal surface of the carpus The long palmar flap, consisting of skin, subcutaneous fat and fascia, is dissected back to the carpometacarpal articulation, after which the flexor tendons are cut long and the carpometacarpal joints opened on their palmar surfaces Disarticulation at these joints is then done, the bleeding controlled, and all the vessels ligated Care is taken to isolate the median, ulnar, and radial nerves, after which they are injected with 95 per cent alcohol, cut high, and allowed to retract The flexor tendon sheaths are closed and those tendons sutured to the surrounding tissues as are the extensor tendons, which will permit flexion and extension at the wrist to be preserved The wound is closed in layers and a small rubber drain is inserted deep in the wound This is removed after the first 48 hours A large gauze dressing and a cock up splint are applied The splint will prevent flexion contractures at the wrist joint From a functional standpoint this type of amputation is far preferable to disarticulation at the wrist joint It is longer and more useful than the stumps in which amputation is higher up

Disarticulation at Wrist Joint

Disarticulation at the wrist joint can be done by using a similar incision to the one just described The lower end of the incision is about the middle of the palm and the dorsal cut is in line with the wrist joint The wrist is then forcibly flexed and the joint opened dorsally by a transverse cut The flexor and extensor tendons are sutured to the surrounding soft tissue and the wound is closed in layers the skin with black silk or silkworm gut

Amputation Through Forearm

As much stump length as possible should be preserved The minimum that will allow the fitting of a satisfactory forearm prosthesis measures 1½ inches from the insertion of the biceps tendon to the bone end of the stump The best stump, when part of the hand cannot be retained, is at the junction of the middle and lower thirds of the forearm Equal anterior and posterior rounded flaps are used The muscles are cut circularly, after which the interosseous membrane is exposed by the knife and the bones sawed through, both bones at the same time and at the same level The usual aperiosteal method is used and pronation and supination will be preserved unless a synostosis occurs between the ulna and

radius The muscle flaps should be sufficiently long to cover the bone ends and to allow suturing of the ends of the opposing muscle groups together The bone ends are rounded off with a rasp and the muscle flaps are then reshaped to make a thin but sufficient muscle covering over them The median ulnar and radial nerves are identified cut high injected with 95 per cent alcohol and allowed to retract Bleeding is of election is at the junction of the middle and lower thirds and while the technic is similar in all parts of the forearm it must be remembered that cosmetically and functionally the results will be much better if we can adhere to the sites of election

Disarticulation at Elbow Joint

Disarticulation at the elbow joint is not a procedure to be recommended In Kocher s

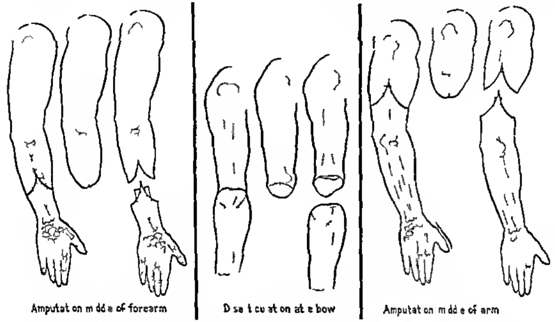


FIG 430 (*Left*) Site of election for amputation in forearm is in middle third Skin incision and division of bone are shown

FIG 431 (*Center*) Disarticulation at elbow joint is not a procedure of choice but occasionally may be advisable

FIG 432 (*Right*) Skin incision and division of bone for amputation through arm Amputation through lower third is preferable but follows the principle of the above drawing

controlled and the deep and superficial flexor groups are sutured together and then to the extensors The fascial flaps are closed with interrupted plain catgut and the skin is closed with silkworm gut or black silk A rubber tissue drain is placed under the muscle flap and can be removed at the end of 48 hours at which time the stump is first dressed

Other types of amputation in the forearm may be necessary at times but the site

operation the incision begins anteriorly over the joint line and extends posteriorly a hand s breadth below the summit of the olecranon The posterior flap will contain the skin and the insertions of the triceps and anconeus while the anterior flap begins at the external condyle and extends downward and medially to one inch below the internal condyle The bones of the forearm are separated from their muscle attachments the nerves identified cut high and

the stumps injected with alcohol The flexor and extensor muscles are sutured over the end of the humerus The wound is closed in layers, the skin with black silk or silkworm gut This type of disarticulation presents a large mass at the end of the arm and is difficult to fit with a prosthesis It does have the advantage of permitting a laced cuff to be placed about the arm and held in position by the knob on the end of the humerus A somewhat similar condition exists in the stump occasionally created when a disarticulation at the knee is necessary

Amputation of Arm

Amputation through the lower third of the arm, with removal of the epicondylar and supracondylar ridges above the flare of the condyles, presents a much more satisfactory stump and gives a better appearance than the preceding but in this type of amputation it is always necessary to have shoulder straps to retain the prosthesis in place In amputations through the lower third of the arm equal anterior and posterior rounded skin flaps are used and the usual technic of isolating the nerves and blood vessels and resuturing the muscles over the end of the bone is followed The aperiosteal method of treating the bone is routinely employed After the muscles are sutured over the bone end, the nerves are injected with alcohol, the bleeding is controlled, and the wound is closed in layers, the skin with black silk or silkworm gut

Disarticulation at Shoulder Joint

Wyeth pins may or may not be used to hold the tourniquet in place, the author prefers them The anterior pin is passed upward through the lower portion of the anterior axillary fold to emerge one inch medial and anterior to the tip of the acromion The posterior pin is entered at a corresponding point in the posterior axillary fold, and comes out within an inch of the tip of the acromion posteriorly The tourniquet of rubber tubing is then applied snugly above the pins and the ends held together with two clamps This permits the bleeding to be under control and allows easy removal of the tourniquet before the end of operation

The Kocher incision begins over the clavicle just external to the coracoid process of the scapula, is carried downward anteriorly, and swings posteriorly at the level of the axillary fold encircling the arm to complete the racket incision Anteriorly the

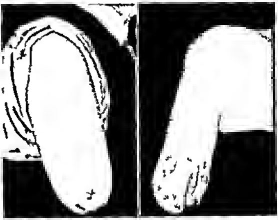
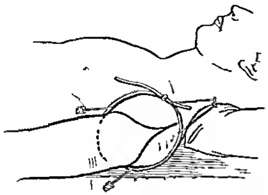


Fig 433 (*Left*) A satisfactory amputation stump of arm (*Right*) An unsatisfactory amputation through arm with redundant soft tissue about end of stump

cephalic vein and the acromial branches of the thoraco acromial artery are ligated The deltoid is divided near its insertion, the capsule of the joint opened over the lesser tuberosity, and the long head of the biceps, the subscapularis, pectoralis major, latissimus dorsi, and teres major are divided at their insertions The capsule with the insertions of the supraspinatus, infraspinatus, and teres minor muscles is detached from the humerus The circumflex arteries may need to be tied The arm is then completely detached and the nerves identified and cut, and the stumps injected in the usual manner with 95 per cent alcohol The brachial artery is identified and doubly ligated with chromic or catgut, after which the small vessels are tied and the tourniquet cau

tiously loosened The bleeding is controlled until the field is dry and the Wyeth pins are then removed and closure begun

The tendons of the pectoralis major and latissimus dorsi, if long enough, are sutured into the margin of the glenoid along with



Disart culat on at shoulder

FIG 434 Disarticulation at shoulder Wyeth pins have been inserted with tourniquet applied and racket type of skin incision outlined

the supraspinatus and infraspinatus, subscapularis and teres The deltoid is inserted deep into the space formerly occupied by the head of the humerus to give contour to the shoulder and is trimmed to fit None of these muscles will have any functional value but are placed to fill dead space The preservation of the circumflex nerves is not important The wound is closed in layers, the skin with black silk or silkworm gut, and a firm pressure Velpeau bandage applied

Amputation through the surgical neck gives a better cosmetic result than a disarticulation, although of no more value from the standpoint of wearing a prosthesis

INTERSCAPULOTHORACIC AMPUTATION

This operation was described by Berger in 1887, and involves the removal of the shoulder girdle en masse Usually, however, the inner third of the clavicle can be left It is rarely necessary to employ such an extensive amputation, but it may be advisable in extensive malignant disease or in a severe crushing accident of the shoulder region It is always attended by shock and the usual methods of treating shock should be followed As the hemorrhage is usually severe, preparation for transfusion should always be made

The patient lies with the unaffected shoulder propped with sandbags, and the affected shoulder region at the edge of the table The skin incision advised by Berger is shown in Fig 436 The incision begins over the sternal end of the clavicle and is carried along that bone to about its middle and then curved downward to the anterior axillary fold exposing well the inner two-thirds of the clavicle This bone is then disarticulated from the sternum or divided at its inner third by Gigli saw, and the muscles and ligaments attached to it are severed close to the bone The attachment of the

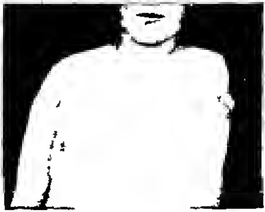


FIG 435 Photograph two years after operation showing disarticulation at shoulder for Ewing's sarcoma of humerus

subclavian muscle is divided at the first rib, exposing the pectoralis minor After dividing the pectoralis minor the axilla is fully exposed and the vessels may be seen The sheath of the subclavian artery and vein is opened and the vein is separated from the artery Two ligatures are applied around the

artery about one inch apart and tied The arm is then held up to empty it of blood Two ligatures are passed around the vein but are not tied until the arm is drained of blood The vessels together with the brachial plexus are then severed, the nerves injected with 95 per cent alcohol, and the incision continued posteriorly and upward to meet the anterior incision The trapezius muscle is severed and the transversalis colli and posterior scapular artery are secured The omohyoid muscle is cut and the supra scapular artery tied The muscles attached to the vertebral border of the scapula are rapidly divided close to the bone and the serratus magnus and finally the latissimus dorsi muscles are severed The wound is closed in layers and rubber drain inserted

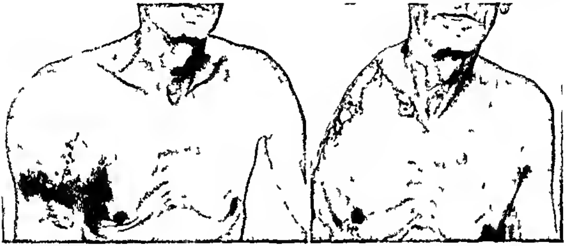


FIG 436 (*Left*) Chondrosarcoma of right humerus (*Right*) Interscapulothoracic amputation well two years later

Part 3 Lower Extremity

GENERAL CONSIDERATIONS

Weight bearing being the prime requisite for the lower extremity, all of our efforts *should be directed toward having an amputation* stump able both to carry the weight of the body (in whole or in part) and to act as a proper lever in locomotion, both of which must be accomplished without pain With the improvement in the construction of artificial limbs very few stumps need to be made for end weight bearing although ideally the stump should bear the whole weight on its end to duplicate what is done in walking It is necessary however, that care be taken in the lower extremity to have a satisfactory covering on the end of the bone Too bulky a muscle mass or too thin adherent skin over the end of the bone will give equally poor results If possible, the suture line should be posterior to the bone end rather than terminal The ideal amputation stump must combine comfort, appearance, and utility, which usually means a stump of good length below the proximal joint It does not mean that at all times the surgeon must save all possible length of the extremity, however, for this may not be in accord with a satisfactory prosthesis

Amputation of the toes will give very little disability, with the sole exception of the big toe In the latter case the gait is seriously interfered with if the entire toe is removed Ankylosis of the interphalangeal or metatarsophalangeal joints will be preferable to amputation If the entire big toe

must be removed every effort should be made to preserve the head of the first metatarsal because it constitutes one of the tripod weight bearing points of the foot If amputation of the second toe is necessary it is much better to amputate a large portion of the shaft and head of the metatarsal

Fig 437 High femoral amputation with unsatisfactory stump end Scar has retracted giving rise to skin folds which are a constant source of skin infection

in order to prevent the tendency to a hallux valgus deformity developing at the big toe joint

If for any reason, such as congenital over lapping amputation of the little toe is required a better cosmetic and functional result is obtained if a portion of the shaft of the fifth metatarsal is cut through and removed as shown in Fig 450 under operative technic

The Lisfranc and Chopart amputations through the tarsometatarsal and midtarsal regions, respectively, are rather generally condemned, both for the application of an efficient prosthesis and for weight bearing As a rule, an equinus deformity of the foot will ultimately result with either of these procedures An amputation through the distal portion of the metatarsals will not require a prosthesis so that it can be recommended if there is tissue available for flaps, and will give a very satisfactory result

There is another type of foot amputation that has been reported by Boyd as quite satisfactory This consists of an amputation of all the bones of the foot with the exception of the os calcis After removal of the cartilage of the tarsal cavity and the upper surface of the os calcis, the tarsal bone is then turned up and allowed to fuse to the tarsal cavity, giving thereby a direct weight bearing surface through the leg and the long axis of the os calcis It is claimed that this procedure gives a satisfactory painless stump, and that the patient walks on the cushion of soft tissue normally about the heel It is, however, a difficult type of amputation to fit with a satisfactory prosthesis because the stump is rather conical in shape and it becomes necessary to have a laced cuff firmly attached about the ankle in order to keep the stump securely within the shoe Disarticulation at the ankle joint proper is always unsatisfactory and is never recommended

Pirogoff s amputation, as shown in Fig 441, is an osteoplastic operation just above the ankle joint, the tibia and fibula being sawed through just proximal to the articular surface of the ankle, and the internal and external malleoli removed This raw bony surface is fitted to the os calcis which has been previously denuded of cartilage If successful, a full weight bearing type of stump follows The objection to it, however, is that it is difficult to fit with a prosthesis and when one is fitted the affected limb is usually longer than the opposite side Also, fusion between the os calcis and the tibia does not always follow, and as this is essential for a painless weight bearing stump the operation is not ordinarily recommended

Symes amputation is a supramalleolar



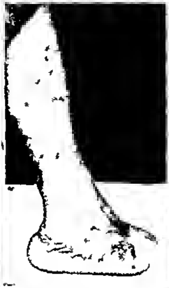
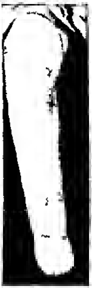



Fig 438 Fig 439 Fig 440 Fig 441

Fig 438 One should never amputate the second toe for distortion of the adjacent toes will result as shown above

Fig 439 Lisfranc amputation on left foot This is usually an unsatisfactory type and is difficult to fit with a prosthesis

Fig 440 A transverse metatarsal amputation is more satisfactory than any other foot amputation, but the site of election in all amputations below the knee is in the lower leg

Fig 441 The Pirogoff amputation gives a clumsy and poor amputation stump and is difficult to fit with a prosthesis



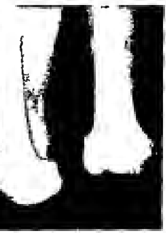



Fig 442 Fig 443 Fig 444 A Fig 444 B

Fig 442 Syme amputation five years postoperative Patient is satisfied but this is usually regarded as a poor type of amputation

Fig 443 X ray of a Syme amputation It is obvious that this type of stump is difficult to fit with a prosthesis

Fig 444 (A) Disarticulation at knee joint giving an end bearing stump (B) X ray of same case

amputation and the stump end is covered by a flap from the heel, differing from Pirogoff's mainly in that the os calcis is entirely dissected out. It is usually unsightly and conspicuous, however, because of the necessarily large ankle, and the artificial limb advantages for the laborer similar to those found in the Pirogoff stump. [This amputation is very favorably regarded in Canada —Ed.]

Disarticulation at the knee joint is ordinarily avoided, but we feel that these have

Fig. 445

Fig. 446

Fig. 447

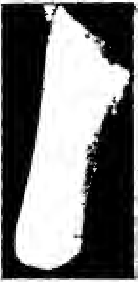


Fig. 448 A

Fig. 448 B

Fig. 445. Very satisfactory tibial stump.
Fig. 446. Bilateral short leg stumps which were unsatisfactory until fibulae were removed. A longer tibial stump is preferred.
Fig. 447. An excellent stump from a Callander amputation.
Fig. 448. Gritti-Stokes amputation showing: (A) Length of femoral stump, (B) thickened skin that has developed on this end-bearing stump. (C) x-ray of Gritti-Stokes amputation.

Fig. 448 C

makers do not think it can be fitted as satisfactorily as a below-the-knee stump. Kirk states that too frequently these stumps are painful but feels that this is probably the fault of the operator. A stump wholly end bearing such as this may present disadvantages... been unsatisfactory because of the type of prosthesis usually fitted to these stumps. A suitable artificial limb is shown in Part 1, and is a most satisfactory end-bearing type after disarticulation at the knee joint.

In the leg the amputation should be at

the junction of the upper and middle thirds and the stump length varies between four and eight inches, depending upon the height of the patient, the ideal length being usually seven inches The bone should be amputated by the aperiosteal method previously described so that no sharp edges or spurs will develop later The fibula should always be cut an inch and a half higher than the level of the tibia, and when the stump is shorter than five inches it is felt that the fibula is better excised completely A short tibial stump is preferable to an amputation through the knee joint or above, but the stump of the tibia should measure at least one and a half inches from the joint line to fit any type of prosthesis satisfactorily, and, of course, a longer tibial stump is better

Above the knee joint we have several types of amputations through the femur which are regarded as satisfactory, but we personally prefer the Callander type This consists essentially of long anterior and posterior flaps, the latter being slightly longer, with the femur sectioned at the condylar flare just proximal to the adductor tubercle The patella is dissected from the rectus femoris tendon and this cavity contracts over the end of the femur to act as an end bearing point It gives an excellent end bearing stump, and because of its length the powerful muscles of the thigh permit excellent control, a requisite in any amputation in the thigh

The Gritti Stokes amputation also gives a long femoral stump The femur is sectioned at its lower end After removing the cartilage from the patella and flattening its posterior surface, the patella is placed over the lower femoral end and permitted to fuse in this position

A slightly different method has been described by Sabanajeff As shown in Fig 457, this utilizes a portion of the upper end of the tibia by ingeniously placing it against the lower end of the femur and retaining the patella and its ligaments on the front of the thigh These three methods of amputation —Callander, Gritti Stokes, and Sabanajeff—are the sites of election for thigh amputations, but occasionally it may be necessary to amputate higher

The principle in the higher amputations is to leave as long a femoral stump as possible The upper limit of the scar line, if the femur is preserved, should be three inches from the perineum Above this point it is so difficult to fit a prosthesis that it is better to disarticulate at the hip joint or to perform an osteotomy through the neck and

Fig 449 Disarticulation at hip joint for osteogenic sarcoma of femur Satisfactory stump for tilt table type of prosthesis

remove the entire femoral shaft With the disarticulation at the hip, every effort should be made to preserve a buttock equal in size and contour to its fellow, and there should be no excess of muscle or other soft parts, for this tends to make an insecure stump for the tilt table type of prosthesis

DISABILITY EVALUATION

In the foot an amputation will not demand as high a functional loss as in the hand, for perfectly obvious reasons The estimation of permanent disability should

depend upon the degree of functional dis ability and this percentage officially varies according to the locality in the United States in which the patient resides The loss of a foot has been approximated as a 25 per cent loss of function in the lower extremity whereas a leg amputation is estimated at 45 per cent In the midthigh one loses approximately 65 per cent of the normal and in the upper thigh 85 per cent Many au thors feel that a femoral stump four inches long or less will give a disability of 100 per

FIG 450 Methods for amputation of toes Excision of metatarsal bone is desirable for all lesser toes except little toe for this toe it is better to osteotomize metatarsal bone as shown

cent for the lower extremity but unfortu nately there is no accepted standard for determining the percentage of function loss

OPERATIVE TECHNIC

AMPUTATIONS IN FOOT

The same method is carried out for toes as in the case of fingers although the great toe should never be disarticulated at the metatarsophalangeal joint if it can possibly be avoided

Any amputation in the forepart of the foot gives a much better type of foot for walking if done through the shafts of the metatarsal bones rather than proximal to them In these cases there must be a long plantar flap and a shorter dorsal one so that the scar is on the dorsum of the stump

Amputation at the metatarsophalangeal joint of the lesser toes is performed by a racket or heart shaped incision as shown in Fig 450 In removal of the little toe it is better to amputate a portion of the meta tarsal shaft also

Lisfranc s Amputation (Tarsometa tarsal) A tourniquet is used The foot is placed in a position of plantar flexion and the incision begins on the outer border of the foot behind the tubercle of the fifth metatarsal bone and extends across the dorsum of the foot a half inch distal to the tarsometatarsal articulation crossing the inner border of the foot at the base of the first metatarsal bone The long plantar flap is then cut reaching from the origin on the first flap to the ends of the meta tarsal bones as shown in Fig 451 After dissecting the skin flap up the extensor tendons are divided just behind the heads of the metatarsal bones and a dorsal flap composed of all the soft tissues is dissected up to above the tarsometatarsal joint carry ing the knife across the base of the fifth metatarsal opening up the joints of the three outer metatarsals and then that be tween the internal cuneiform and first metatarsal Some operators advise sawing through the metatarsals just below their bases feeling that this will give equally good results and is a great saving of time and trouble but the true Lisfranc amputa tion is an amputation at the tarsometatarsal junction

The long plantar flap is now cut across the knife being held vertically to the skin the soft tissues are divided and the tibialis

anticus, the peroneus longus, and the brevis are sutured into the periosteum or some tissue adherent to the bone in order to preserve some of the foot balance The long worm gut, always having the suture line on the dorsal surface of the stump and not on the end

Chopart's Amputation (Midtarsal) A

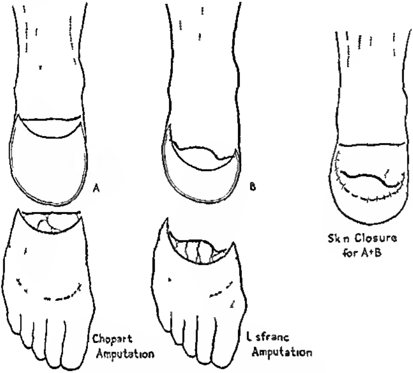


Fig 451 Chopart and Lisfranc amputations

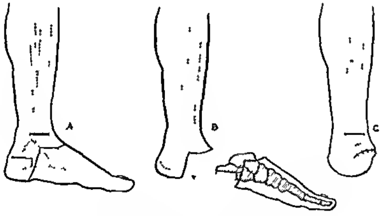


Fig 452 Pirogoff amputation

extensor and flexor tendons of the toes are then attached to the adjacent tissue, the subcutaneous tissues are closed with plain catgut, and the skin with black silk or silk-

tourniquet is applied to the thigh and a short dorsal and long plantar skin flap made as shown in Fig 451, making the transverse dorsal incision through the skin of the in-

step two inches below the ankle joint. After the tendons and muscles are cut and the tarsal bones exposed, a small longitudinal incision is made on each side reaching to below and in front of the corresponding malleolus The astragaloscaphoid and calcaneocuboid joints are opened and disarticulated at this line This leaves a weak joint because the rest of the foot is amputated A tenotomy of the tendo achillis should be done at the time of the operation or later to lessen the tendency toward development of equinus deformity It is not an operation that is recommended

Amputations at Ankle Region

Pirogoff Operation This is an amputation just below the ankle joint It is rather difficult to perform and is rarely advisable The foot is flexed at a right angle to the leg and the incision runs from the tip of the internal malleolus across the sole a little in front of the long axis of the tibia ending at a point near the tip of the external malleolus, and the dorsal incision is a curved one a half inch in front of the lower extremity of the tibia The skin flaps are dissected back, and after disarticulation at the ankle joint the tibia and fibula are cut across just proximal to the articular surface of the tibia, removing the articular cartilage and the internal and external malleoli The os calcis is cut obliquely, leaving a considerable portion of the bone in the heel flap, and then the raw bony surface of the os calcis is brought into contact with the raw under surfaces of the tibia and fibula The flaps are sutured into position expecting a bony union between the os calcis and the leg bones If this occurs, a satisfactory result may ensue with direct weight bearing, and the patient will not need an expensive type of prosthesis It is an operation not often employed

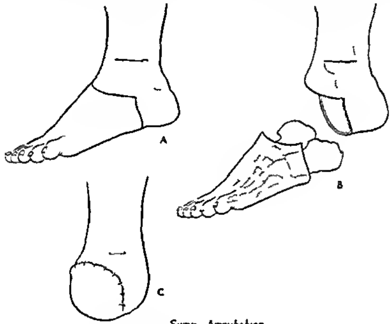


FIG 453 Syme amputation

Syme s Operation This is a supramalleolar amputation and the stump end is covered by flaps from the heel, differing mainly from the Pirogoff operation in that the os calcis is entirely removed along with the foot The incision is made from the tip

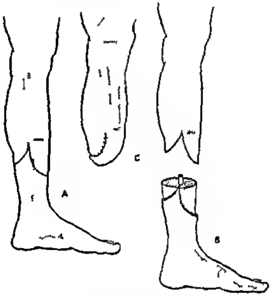
of the external malleolus to a point a half inch below the internal malleolus across the sole being slightly curved toward the heel The dorsal incision is across the front of the ankle joint as shown in Fig 453 The tendo achillis is divided close to the os calcis and the latter dissected from the heel flap leaving as thick a pad of soft tissue as possible *The tibia and fibula are sawed through a half inch above the articular surface of the tibia and at right angles to its long axis* and all the tendons trimmed so they will retract into the wound All the nerves must be dissected from the *heel flap* The deep layers are sutured with plain catgut and the skin with black silk or silkworm gut There is usually some redundancy of the heel flap This makes the closure difficult and the operation rather objectionable These stumps are not capable of direct end bearing without some pain and because they are so close to the ankle joint the stump is a rather unsightly one As a rule these two amputations —the Pirogoff and Syme's give less satisfactory results than amputations through the middle third of the leg and the extra leg length they give is of no particular advantage

Amputations Through Leg

Middle Third The stump length is measured from the point of insertion of the internal hamstring tendons into the tibia to the bone end of the stump and this measurement is taken with the knee flexed at a 90° angle A seven inch tibial stump is considered the ideal one and the suture line should lie just posterior to the bone end never anterior

Anterior and posterior skin flaps are made the incision beginning above the selected saw line and curving downward the flaps being dissected back to the saw line The posterior flaps are slightly shorter than the anterior in the relation of three to two The skin on the posterior surface is freed for two or three inches and the muscles cut through with a long bladed amputating knife a little below the level of the saw line but sufficiently long to cover the stump end The muscles are then cleaned back from the bones and the periosteum is removed circularly from the tibia and fibula for a quarter of an inch as a cuff proximal to the projected saw cut The bones are then sawed through The anterior crest of the tibia is beveled as shown in Fig 454 and the fibula is divided an inch and a half to two inches higher than the tibia

After sawing through the leg bones at



Leg amputation at site of election

Fig 454 Amputation in middle third of leg

right angles to the leg the sharp corners of the tibia and fibula are rounded off with a rasp The bone dust is flushed out of the wound with normal saline The nerves and blood vessels are treated in the usual way care being taken to identify the anterior and posterior tibial and peroneal arteries and the anterior and posterior tibial and musculocutaneous nerves

Before closing it may be necessary to trim away some of the redundant muscular tissue so that it can be brought over the end of the bone The tourniquet is then re

moved and the smaller bleeders and muscle ooze controlled The wound is closed in layers the skin with black silk or silkworm gut and a drain of rubber tissue inserted in the usual manner With a short tibial stump it is of some help in avoiding knee-flexion contracture to place the limb in plaster in the extended position following the wound closure

Disarticulation at Knee Joint

This type of operation is not recommended because of the difficulty of fitting and the patella completely removed Internal and external hamstring tendons are cut long the popliteal artery ligated and the nerves identified and injected with 95 per cent alcohol after section The internal ligaments of the knee are divided and the disarticulation is completed The wound is closed in layers so arranged that the scar will be on the posterior aspect and not on the terminal part of the stump Because the condyles of the femur are unequal in length and uneven in contour the articular surface of the femur when covered with healthy

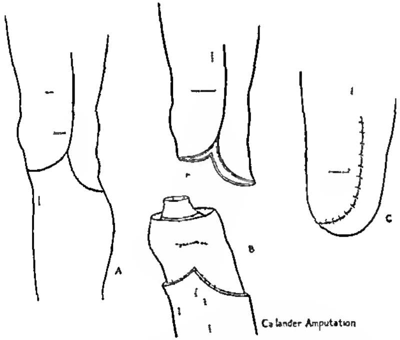


Fig 455 Callander amputation this gives an excellent end bearing stump

the stump with a prosthesis although a satisfactory limb can be obtained if fitted with the type of prosthesis illustrated in Part 1

Under tourniquet a long anterior flap and a shorter posterior flap are made and healthy skin included in the anterior flap to a point two inches below the tibial tubercle The ligamentum patellae attached to the anterior tubercle is divided the knee joint opened, skin is usually tender to pressure and does not make an ideal end bearing stump

Femoral Amputations

The femoral amputations may be divided into (1) the long femoral stump such as Callander or Gritti Stokes (2) midfemoral amputation and (3) high amputation i e above the middle third The upper limit of the femoral stump should be a three-inch

stump as measured from the perineum, and if the amputation has to be higher than this a disarticulation at the hip or a saw cut through the neck of the femur is to be preferred

Callander Amputation (Low Femoral Stump) No tourniquet is used The patient is placed on his back with the knee of the affected extremity flexed slightly, and skin incisions are made as shown in Fig 455, so that there are slightly unequal anterior and posterior flaps Two inches proximal to the most prominent part of the medial femoral condyle is the point at which the incision begins and it runs downward in the groove between the vastus medialis and sartorius muscles The adductor tubercle on the medial side of the lower end of the femur is easily identified It is the point of insertion of the adductor magnus muscle and the point at which the femur is later divided The skin incision curves over the anterior surface of the tibia to cross the tibial tubercle The patellar tendon is divided at its insertion Another incision starting three fingerbreadths proximal to the lateral femoral condyle is made, extending down the lateral aspect of the leg between the tensor fascia lata and the biceps femoris muscle and crossing the front of the tibia to meet the inner incision One does not at this time divide the tendon of the biceps

Medial and lateral incisions are then carried obliquely, posteriorly, and inferiorly as in Fig 455, until they meet on the calf of the leg about the midpoint of the belly of the gastrocnemius muscle These two long amputation flaps consist not only of the soft parts of the lower thigh, but of a considerable portion of the soft parts of the leg On the medial side of the thigh and knee the deep fascia is divided and this exposes the popliteal fascia and the popliteal space The medial hamstring tendons are identified, divided, and allowed to retract into the depth of the wound The tendon of the adductor magnus is divided at its insertion into the adductor tubercle, giving free access to the popliteal vessels and nerves The popliteal artery and vein are withdrawn slightly from the wound, clamped, ligated, and divided as far distally in the popliteal space as possible The common peroneal and tibial nerves are then identified, ligated, and divided, after which the proximal portion is injected with 95 per cent alcohol The knee is then rotated and the lateral longitudinal incision deepened

The biceps tendon is identified and severed at its insertion into the head of the fibula The posterior flap is then dissected up but the fibro areolar tissue in the popliteal space is left largely undisturbed The capsule of the knee joint is divided and the anterior flap containing the patella is dissected upward, after which the sesamoid bone is removed from the quadriceps tendon

The femur is now sawed through just proximal to the adductor tubercle and the bone ends rounded off with bone cutting forceps and a rasp, and the usual cuff of periosteum removed to make an aperiosteal stump The wound is thoroughly flushed out with warm saline and the muscle bleeding controlled The flaps are allowed to fall loosely together and held with silkworm gut or skin clips applied at such intervals as to keep them in fair approximation Closing the wound in this loose manner does not put any of the structures under tension and permits the hamstring muscles to contract The quadriceps is drawn downward over the bone end so that the cavity produced by the removal of the patella fits over the end of the femur The flaps appear unusually long and cumbersome and it is wiser to support the entire extremity on a long bass wood splint for the first week while the shrinkage process is beginning

There is usually a considerable amount of ooze during the first few postoperative days and it may be necessary to dress the wound daily No rubber drain is inserted and it is rather remarkable that as convalescence proceeds the posterior flap retracts gradually until the suture line is well posterior

and one or more inches proximal to the end of the bone An excellent end bearing stump results (See Callander Jour Amer Med Asso 105 1746 1753)

Gritti Stokes Amputation (Low Femoral Stump) This supracondylar amputation is superior to a division of the bone at a higher level for it preserves the strong thigh muscles and gives good control of the stump

Long anterior and short posterior flaps on the posterior and posterolateral surfaces of the thigh are cut so that they can be retracted to the saw line, after which the *bone is sawed through* at a right angle to the thigh about one inch proximal to the adductor tubercle

The femoral artery and its branches are isolated and doubly ligated with plain cat gut After identifying the sciatic nerve, it is sectioned injected with 95 per cent alcohol and allowed to retract. The hemorrhage

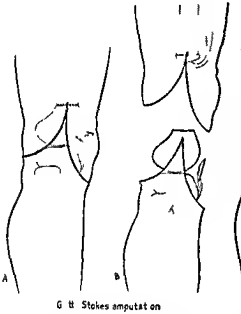


Fig 456

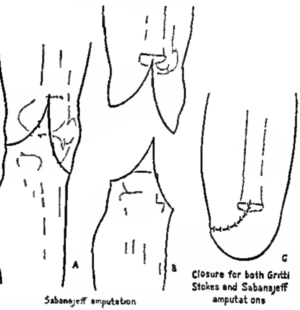


Fig 457

Fig 456 Gritti Stokes amputation This gives a good low femoral stump

Fig 457 A Sabanajeff amputation which is a low femoral stump is not often employed, for frequently it is not advisable to utilize the tibia in these low femoral amputations (A) and (B) Skin closure is same for this and the Gritti Stokes amputation (C)

are made The anterior incision starts just above the knee joint and curves gradually downward across the anterior surface of the knee midway between the patella and the tubercle of the tibia The posterior curved flap is then formed and the fascia cut along the skin line incision The knee joint is opened and the skin flap with the patella and other soft parts is dissected back to the anticipated saw line of the femur in the supracondylar region The structures from the smaller blood vessels and muscle ooze is controlled, after which the tourniquet is removed and any residual bleeding controlled

The articular surface of the patella is then removed, leaving a smooth, flat bony surface, and the wound thoroughly flushed out The prepared patella is then brought over the end of the femur and fitted into position and the patellar tendon is sutured to the periosteum on the posterior surface

of the femur, it is not usually advisable to transfix the patella to the femur by any form of fixation A rubber-tissue drain is inserted and the wound is closed in layers

Sabanajeff Transcondyloid Amputation (Low Femoral Stump) The Sabanajeff transcondyloid amputation is done very much in the same way as the Gritti-Stokes except that the upper end of the tibia is utilized to fit over the lower end of the femur as shown in Fig 457, and the patella is left in situ This amputation is rather difficult to perform and it presumes the presence of a healthy knee joint Kirk feels that the Gritti Stokes is a better method than that of Sabanajeff

Midthigh or midfemoral amputation is done using the slightly longer anterior skin flap and covering the bone end with a thin pad of muscle formed by suturing together the anterior and posterior muscle groups This muscle pad becomes fibrous tissue and acts very well as a weight bearing medium The bone end is treated in the usual manner with a cuff of periosteum removed The vessels are doubly ligated and the nerves injected with alcohol in the usual manner It should be remembered that the adductor muscle will retract more than the others and therefore should be cut longer The wound is closed, a rubber drain inserted, and the skin closed with silkworm gut or black silk

High Femoral or Upper Thigh Amputations From a prosthetic standpoint, it is better to amputate through the neck of the femur or disarticulate at the hip than to amputate above the level of the three inch stump If the stump is more than three inches long, one can amputate by the flap method, making the anterior flap slightly longer than the posterior one, and using Wyeth pins to hold the tourniquet as in disarticulation of the shoulder The general principles of anchoring opposed muscle groups to other muscle groups should be observed, the artery and vein doubly ligated in the usual manner and the nerve stumps injected with 95 per cent alcohol and permitted to retract A rubber drain is used and the wound is closed in layers, closing the skin with black silk or silkworm gut By using the Wyeth pins hemorrhage can be well controlled The tourniquet is not

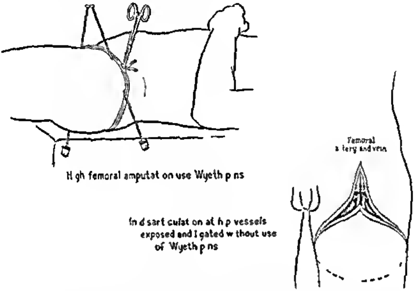


Fig 458 Showing use of Wyeth pins in high femoral amputations In disarticulation at hip, artery and vein are doubly ligated

removed until the major blood vessels have been doubly ligated

Disarticulation at Hip Joint

The racket type of incision is used and a tourniquet is not necessary The femoral vessels are easily located and a skin incision is made longitudinally over the femoral artery and vein, beginning at the center of Poupart s ligament The common femoral artery and vein are carefully isolated and removed from their sheath The artery is doubly ligated and the end clamped throughout the operation The limb is then elevated to drain the blood from the veins and the femoral vein is then ligated in the usual manner Care must be taken that the common femoral artery is ligated above the point of origin of the profunda, otherwise the hemorrhage will be profuse

The incision is then swung downward and inward across the thigh to a point about three and a half inches below the groin on the inner aspect and curved on the posterior surface to reach the base of the greater trochanter It is then extended upward on the lateral surface to meet the anterior incision The skin and fascia are dissected back and the adductor muscles cut close to their origin from the pubic bone

The extremity is held by an assistant and easily moved into an attitude of adduction or abduction to permit quick sectioning of muscle tissue and satisfactory exposure The muscles on the lateral surface of the thigh are divided, together with the gluteus medius, piriformis, obturator, gemelli, and gluteus minimus The muscles on the front, consisting of the tensor fasciae femoris, rectus femoris, sartorius, and psoas, and the capsule of the hip joint are cut across

The femur is disarticulated, and all of the remaining muscles and soft parts are cut through just distal to the tuberosity of the ischium The entire lower extremity is removed All bleeding is controlled The muscle flap is sutured into the acetabulum with the intention of filling all dead space, and the wound is closed in layers with a rubber drain inserted deep into the acetabular area An attempt is made to form a buttock equal in size and contour to its fellow, and the suture line should be located as far as possible from the rectum to prevent soiling There must be an excess of muscle tissue or other soft parts in this type of amputation for the weight is borne on the bony landmark of the tuberosity of the ischium and if this bony mass is too bulky it tends to give an insecure seat and becomes pinched by the artificial limb

Part 4 Prostheses

PREPARING AMPUTATION STUMP

Forty eight to 72 hours following the amputation the wound should be dressed and, if the flap method is u ed, the rubber drain removed. If the guillotine type of amputation is used it is usually wise to begin skin traction very soon after the operation, and by gradual traction on the underlying skin and soft parts one may be able to cover the end of the bone in a very short time

In those cases with primary union by the flap method, the stitches can be removed in about two weeks and attention can be early devoted to shrinking the stump by the wearing of a snug pressure bandage This is applied very tightly in the morning and it is desirable to wear it all day very snugly applied On retiring at night the bandage is removed Ordinarily a four inch Ace bandage makes a very satisfactory pressure bandage, and is particularly desirable in cases of high femoral amputation in which the excess amount of fat and other soft tissue makes the application of a prosthesis difficult

The stump may be toughened by fre

quent cold water baths and vigorous rubbing with a coarse towel which should be begun cautiously and continued until the stump can be rubbed as freely as any other part of the body Cocoa butter, glycerine or olive oil should be well rubbed into the skin at night and the limb bathed in a salt water solution allowing the water to dry on the stump to aid in toughening the skin The use of alcohol rubs is not advised for it removes the oil from the skin and has a tendency to make it dry and tender Baking and massage may be useful and any of these treatments can be recommended to toughen the end of the stump but the trauma must not be sufficient to produce irritation

One may slap the stump with the open palm of the hand or paint the skin with tincture of benzoin before applying the daily pressure bandages and by these methods the patient soon learns not to fear hurting the amputation stump and can begin cautious weight bearing with the stump placed against the mattress Early controlled mobility of the stump is greatly to be desired for a considerable amount of strength is necessary satisfactorily to manipulate and control any prosthesis Therefore the shorter the stump the greater the need for controlled muscle power A stump protector as well as a pressure bandage later is of use as it will permit some degree of protected weight bearing to be begun and the stump protectors often save the stump from being struck by a crutch or may prevent bruising the stump end while it is comparatively tender

The use of a pillow under the stump while the patient is convalescing should be discontinued as soon as possible for there is a very real tendency for flexion contractures to develop particularly in the short stump The use of a basswood splint or plaster of paris dressing to hold the proximal joint completely extended during the first few weeks after the operation may prevent flexion contractures After this the patient must quickly become accustomed to moving about on crutches for this not only builds up the general tone of all the muscles but permits him to acquire a sense of balance He must learn to stand erect with his head up when using crutches and carry the weight on the hands instead of the axillary portion of the crutch learning early to toughen and control the stump Occasionally it is obvious that the limb is becoming irritated and sore following these treatments and of course as long as the redness and marked sensitiveness are present the above methods of preparing the stump for the prosthesis must be discontinued Occasionally an underlying osteomyelitis may be the cause of the slow convalescence and an x ray should be taken if there is any evidence of local inflammation

From an economic and psychologic standpoint every effort should be made for the patient to return quickly to his former occupation as a wage earner The ordinary amputated stump will undergo a certain amount of shrinkage for approximately 12 months after the operation but the majority of stump changes will occur within the first six months so that as early as possible the patient should be fitted with some type of artificial limb The accommodation of the amputated stump must be a thorough gradual and continuous one for there are many changes within the skin in the underlying soft tissues and in the bone that nature must make in order that the amputee can wear any type of prosthesis comfortably It means that the bone must be the point of insertion of the divided muscles so that a firm fibrous cushion securely under the bone end will allow complete control of the stump

While it is obviously a very expensive proposition to fit patients with several prostheses before the limb has shrunk to its ultimate size it is not expensive to make a plaster pylon which will permit weight bearing and it is advisable in certain instances The need of a temporary prosthesis will evoke great discussion among the limb

makers for the majority favor fitting the permanent limb at the beginning and making necessary alterations to the socket later to compensate for the shrinkage. They feel it is better if the patient can start walking on the type of limb which he will ultimately use. While the plaster pylon is a very inexpensive type of prosthesis, it does not teach the patient to accustom himself to the

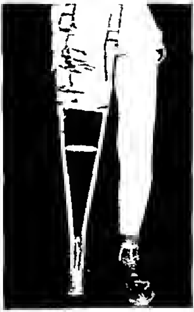


FIG. 459. An inexpensive and easily made plaster pylon.

foot and knee action as will the permanent type of artificial limb; however, the plaster pylon as a temporary prosthesis is at times a very useful one and is made as described below.

MAKING TEMPORARY PROSTHESES

There are many types of temporary prostheses which may be utilized, using molded leather, a light metal, or fiber material, but we believe the most generally applicable and least expensive one is made using plaster of paris and an ordinary crutch. This temporary prosthesis is made by wrapping plaster bandages about the individual stump and incorporating into this plaster-of-paris bucket the lower half of a crutch. These materials are always available, are inexpensive, and fulfill a necessary requirement for early weight bearing.

In order to make this pylon, an ordinary good grade of dental plaster of the quick-setting variety is used, that is, one setting in two or three minutes. Plaster bandages are wrapped about the amputated stump snugly, the stump first being covered with a tubular stockinet extending well up above the margin of the planned bucket. If it is a thigh stump a strip of cardboard six inches wide and long enough to encircle the stump should be placed around it and held in place with adhesive straps. This simple method serves as an appliance for molding the lower end of the plaster bucket and leaves the conical bottom open. Four- or six-inch plaster bandages are then evenly applied. One should make the casing as light as possible, and mold it well along the upper border which will be in direct contact with the bony prominences of the stump. The stump end must be held perfectly still while the plaster hardens so the muscles will not distort the contour, and the position must be that which the limb will assume in weight bearing. This position in the thigh usually means that the hip is extended and the amputation stump is in about 10° abduction. After the plaster is set it is carefully rounded on its superior border, and if the bucket is being made for a mid-thigh stump care should be taken to mold the plaster well about the tuberosity of the ischium, the gluteal fold, the perineum, and over the greater trochanter region. This will permit the completed mold to extend obliquely under the tuberosity of the ischium following the contour of a well-fitting Thomas ring splint and will allow the edge of the pylon to receive much of the body weight.

If the leg is the part being prepared, as would be necessary in the amputations about the foot, a sufficient window on the anterior surface of the plaster is cut out to

permit the amputated extremity to be withdrawn, after which this window is strapped back into position The plaster casing or bucket is then removed from the stump and set aside for a day or two to dry thoroughly

In foot amputations, lateral side pieces are fixed into the plaster with the ends projecting a trifle below the end of the ankle, and a wooden block of necessary length is fitted to this so that the patient walks in his plaster mold with the weight evenly distributed Later, after the sensitiveness disappears, there may be inserted in the bottom of the socket different thicknesses of felt, which are gradually removed until the entire weight is borne on the stump end A light fiber material has been used to make the prosthesis lighter, but for civil practice the most easily available and inexpensive material is plaster of paris It may be desirable to make these pylons waterproof, and if so, they can be shellacked or a waterproof type of material such as Castex can be used

An ordinary wooden crutch is used After removing the hand grip, the crutch is sawed to the proper length and beveled so that it will fit smoothly against the plaster bucket After trimming the lateral side bars and cutting them the desired length the crutch is fitted to the medial and lateral aspects of the plaster socket At this point careful alignment is absolutely necessary so that the weight bearing will be in a straight line from the stump end The crutch is cut to fit the shape of the bucket, and the cross bar ordinarily used for gripping and which was removed, is replaced so that there will be no tendency of the crutch to crush against the socket while the plaster is soft Also, by replacing the hand grip, the stability of the crutch is increased Plaster of paris bandages are then wound around the wooden upright, holding the crutch securely against the socket

A more cumbersome method of making a weight bearing extremity is to use a simple peg leg incorporated into plaster, firmly fixing it in the plaster mold This gives a heavier and more cumbersome prosthesis or pylon, but in the absence of a crutch it may be used After completing the temporary prosthesis it is sawed off a half inch shorter than the normal extremity and fitted with a rubber tip The plaster pylon is then suspended by a shoulder strap of two inch webbing with a piece of elastic webbing sewed into its middle This is carried under the crutch handle and over the shoulder The two ends are then buckled in front and secured to the upper side of the bucket by straps or buckles as shown in Fig 459 The prosthesis is worn with an ordinary woolen stump sock which furnishes the necessary padding over the end of the limb As the smaller end of the bucket has been left open, the sock can be passed through this opening and pulled down so that it will not be too firmly pressed against the soft parts while weight bearing A pelvic band is often used and preferred by the patient to hold the prosthesis firmly in place These temporary side bearing prostheses are quite satisfactory and very cheaply made

If an end bearing type of stump is desired, a layer of felt is placed in the end of the bucket and passed over the outside, making a bottom to the conical plaster cavity

If a short amputation is being treated, care must be taken not to have a sharp edge of plaster jut against the tuberosity of the ischium, but to have the edges everted so that the patient sits in this cuplike container

In making a bucket for a temporary prosthesis following disarticulation at the hip, the patient supports himself on the opposite extremity while a piece of tubular stockinet is pulled up from below and sewed over the body The plaster bandages when applied will include the whole pelvis The plaster is then well padded and well molded to the bottom and sides of the stump, extending above the anterior superior spine and crest of the ilium on the affected side Fixation

of the bucket to the body is secured by webbing straps going around the pelvis to prevent lateral displacement, and around the opposite shoulder is placed elastic webbing. This webbing passes beneath the bucket and is fixed to it so that, with a hip disarticulation the amputee has a fairly comfortable appliance and walks about as

In amputations below the knee a fiber type of artificial limb is extremely satisfactory. It has a lacing above the knee and a hinge joint at the knee. The United States Army uses a temporary leg prosthesis made of fiber which may be bought in quantities and may be easily adjusted as the limb undergoes shrinkage.

FIG 461

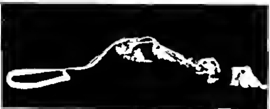


FIG 460 FIG 462 FIG 463 FIG 464

FIG 460 Tilt table type of prosthesis for disarticulation at hip. Sometimes a shoulder strap is used in addition to wide band about the waist. (Courtesy, J E Hanger Co, Inc St Louis Mo)

FIG 461 Below elbow arm showing glove usually worn over hand and shoulder strap that loops over opposite shoulder. Pull cord is attached to this shoulder loop and controls movement of thumb. Lacing on posterior surface of forearm allows for shrinkage and is not shown in the photograph. There is a three-position elbow lock, adding to value of limb. (Courtesy, Miracle Artificial Arm Co Chicago, Ill)

FIG 462 Above elbow arm having a crowfoot type of single-pull harness. Hook is controlled by opposite shoulder motion and dress hand can replace hook apparatus for dress purposes.

FIG 463 Prosthesis for Chopart and Lisfranc type of amputation. This amputation is difficult to fit and is employed infrequently. (Courtesy, J E Hanger Co, Inc St Louis Mo)

FIG 464 Prosthesis employed in Pirogoff and Syme amputations. This is a difficult amputation stump to fit and is not frequently employed. (Courtesy, J E Hanger Co Inc, St Louis, Mo)

well as a patient with an ankylosed hip. These patients cannot sit down easily, however, but because the muscle pad is not excessive a temporary prosthesis is usually unnecessary. With this type of stump a few weeks are adequate to fit the patient with a permanent prosthesis of the so-called table tilt type as shown in Fig 460.

It must be remembered that the patients who become habitually accustomed to the use of crutches sometimes develop crutch paralysis from pressure of the crutch in the axilla upon the brachial plexus. The treatment is temporarily to discontinue the use of crutches and to enforce weight bearing on the hand grip instead of in the axilla.

ARTIFICIAL LIMBS

Many artificial limb manufacturers insist that the amputee should begin the use of a permanent prosthesis as soon as any weight can be borne upon the stump, and that the patient should spend all of his efforts toward learning to control the stump and learning to balance his body

Wearing a limb is undoubtedly in some cases the best way to develop the stump and its use has a great psychologic effect Crutches in this type of individual may retard rather than lessen the patient s period of convalescence, and he does not have to overcome some of the wrong walking habits he may develop with the use of pylon or temporary prosthesis

The growing child will easily adapt himself to the permanent artificial limb and it is estimated that the ordinary limb will last a child from three to five years It is true that in growing children the bone in the amputated stump will grow proportionately faster than the soft tissues, and as has been pointed out an epiphyseal arrest of the proximal growing centers may be very useful

No hard and fast rule can be laid down for all types of patients but it is felt that in the average case met with in civil practice, and particularly in children the patient is saved some time and worry if the permanent artificial limb is fitted to the amputation stump as soon as the local condition will permit The artificial limb should be obtained from well established firms or artificial limb makers and it must possess *comfort strength and durability* Various types of strong light material have been employed such as some of the lighter woods metals or fiber compositions and while there are certain special features offered by different limb makers the amputee cannot go far wrong if he chooses a well established company which will cooperate with the surgeon in trying to solve the individual problem presented

For Upper Extremity

A utility hand or single and double hook limb is most satisfactory for working and, if possible, a dress hand for cosmetic reasons is advisable These hook hands permit the opening of the jaws by a slight shoulder movement and are capable of hard service for holding or lifting objects The mechanical hand can handle light objects with ease and most of them have a simple mechanism of opposing the thumb to the semiflexed fingers and, in the more complicated hands often some finger control The highest type of efficiency for artificial limbs for the upper extremity seems to have been reached with the cineplastic appliances which are described elsewhere As the value of the upper extremity primarily depends upon dexterity of movement it is obvious that the loss of the upper extremity is not so easily compensated for as the loss of the lower In order to accomplish work requiring heavy labor the simpler mechanisms are advised A sedentary occupation will lend itself to utilization of the highly complicated mechanical limbs

For Lower Extremity

In the foot the Lisfranc and Chopart amputations are difficult to fit with a prosthesis They can be fitted with a leather boot which is padded to relieve pain and tenderness but as a rule these procedures give too short a stump In the Pirogoff or Syme amputations an unsightly and conspicuous stump with a large ankle is produced and in all four of these operations *the artificial limb maker would prefer that* the patient have a satisfactory below the knee amputation, for he feels that a very satisfactory artificial foot can then be made and that an inconspicuous practical below the knee prosthesis is very much more desirable

The below the knee stump is ideally seven inches long and can be fitted with a natural flesh color leg and a laced cuff over

the thigh which will permit adequate control This can be made very light and strong The higher type of below the knee amputation can be fitted with a knee bearing type of artificial limb which is useful for the very short tibial stump limb In this type of prosthesis the weight is borne on the flexed knee which rests on a suspended satisfactory from the standpoint of the artificial limb maker In the middle and upper thirds of the thigh the weight will be borne largely on the ischium, and in a very short thigh amputation the artificial limb must be held firmly to the body by shoulder straps, or in certain cases a wide band may fit comfortably and smoothly about the hips This

Fig 468



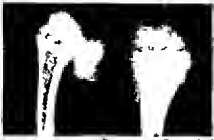



Fig 465 Fig 466 Fig 467 Fig 469 Fig 470

Fig 465 Below knee prosthesis fitted on an ideal seven inch leg stump, showing control of limb

Fig 466 Knee-bearing prosthesis which can be satisfactorily used for very short tibial stumps (Courtesy, J E Hanger Co, Inc, St Louis, Mo)

Fig 467 Prosthesis for amputations above knee A middle or lower femoral stump is desired (Courtesy, J E Hanger Co, Inc, St Louis, Mo)

Fig 468 X ray of short tibial stump, knee-bearing type of prosthesis shown in Fig 464 was employed

Fig 469 Case of infection from *Bacillus welchii* (*Clostridium perfringens*) Mid femoral amputation was done and satisfactory stump resulted

Fig 470 Stump needing remodeling, at which time upper tibial epiphysis was destroyed, as described in text

rubber and leather sling, giving an end bearing stump with its laced cuff about the thigh

When disarticulation at the knee is necessary, a satisfactory type of prosthesis has been shown, and here shoulder straps or pelvic straps are not required because the bulbous end of the femur will permit a snug lacing about the thigh, giving control of the artificial limb

In the thigh, it may be stated that all amputations through the middle third are band type has the advantage of holding the wearer firmly in the socket, whereas, with the shoulder control type, the stump has a tendency, when the body is bent forward, to drop away from the prosthesis

With disarticulations at the hip or short amputations two inches or less from the crotch, the tilt table type of artificial limb with the broad pelvic band is quite satisfactory, but sometimes may need to be reinforced by shoulder straps In this prosthesis the buttock rests on the top of a

padded socket and permits a very satisfactory control of the leg by means of a special knee movement Over all stumps there are worn stump socks which are preferably made of wool In some instances the patient's skin may be able to utilize a silk stocking which will give a very accurate fit but the woolen sock is usually preferred

In certain artificial limbs there is an adjustable leather socket as shrinkage of the limb occurs, but this is not often desirable as the play of the adjustable leather socket to some extent limits the active control of the prosthesis

Part 5 Complications and Causes for Re-amputation

Shock The condition of shock related to the injury that has been received is not particularly uncommon, and this has been discussed in another chapter On the other hand, shock as a result of the operation itself may be severe and alarming Occasionally local injection of the nerve trunks prior to amputation or disarticulation lessens the possibility of this type of shock Adrenalin infusions, local application of heat, tilting of the table, and lowering of the patient s head should all be resorted to As a rule, however, if the patient s fluid content has been carefully raised by preoperative, operative, and postoperative infusions or transfusions, shock may be kept at a minimum [See Chapter 22 for complete discussion of shock —Ed]

Hemorrhage Operative hemorrhage will rarely be a complication, although it does occur The bleeding encountered during the operation is easily controlled, and the larger vessels should be doubly ligated with chromic catgut If the tourniquet is so applied before the operation that it can be loosened gradually, the smaller bleeders can then be easily identified and tied If the tourniquet should suddenly loosen, digital pressure proximally over the larger arteries, such as the femoral in the groin and the brachial in the arm, will have to be made very quickly In operations about the hip and shoulder, Wyeth pins are passed through the muscular tissue about the shoulder and hip to hold the tourniquet from slipping as described under Operative Technic for these regions This simple method will permit the tourniquet to be wrapped about a fixed point and technically simplifies the operation

Gas Infection It is advisable to watch the tissues carefully for any evidence of gas or air formation which may suggest the *Bacillus welchii* following any amputation in severely crushed and traumatized limbs The use of deep x ray therapy pre and postoperatively in this type of wound is advisable Large doses of specific serum in controlling early cases of gas infection, as well as the local use of sulfanilamide, will sometimes inhibit the growth of the gas bacillus and save patients from an amputation (See also Chemotherapy, Chapter 22)

Tetanus In all compound wounds there is also the danger of tetanus, but the use of massive doses of antitetanic serum will decrease the danger of this complication If, however, any subsequent surgery is necessary on these severely compounded wounds, it is felt the serum should be repeated when ever subsequent surgery becomes necessary within a year from the original trauma

Flexion Contracture Flexion contracture at the proximal joint may occur if the amputation is done close to the joint line, and this is particularly troublesome in the short leg stumps and high femoral amputations We have found that the most satisfactory method to prevent these contractures is to apply plaster-of paris or basswood splints to the amputated stump at the time of operation, running this support well beyond the proximal adjacent joint and holding the leg in the fully extended position until wound healing has occurred In some instances these contractures have re

quired delay in the application of a prosthesis until they could be corrected by open operation This complication has not arisen following the use of the plaster of paris splint

Infection of Hair Follicles This sometimes causes considerable annoyance, particularly to the male patient When these infections do not respond to the usual measures, it is probably better to remove the hair by electrolysis

Summary

In a series of 70 cases of amputation recently reported 28 6 per cent of the cases required re amputation and the following were the most common causes found

There may be infection of the deeper tissues due to preoperative, operative, or post operative causes If amputation is done through an infected area, subsequent drainage will delay the healing process Sometimes the gross appearance of the tissues will not give evidence of the pre existing infection These wounds heal slowly, and if there is any reason to suspect a flare up of a latent infection, it is better not to close the skin tightly, but to allow adequate drainage

An operative infection is another complication that must always be considered and too frequent dressings will also open an added channel to the possibility of infection An osteomyelitis of the underlying bone is a complication that should always be considered in draining a stump accompanied by other evidences of local inflammation An x ray picture of all amputated stumps which do not heal per primam may give valuable information to the operator as to the cause of the underlying pathology

A disproportion of growth in the amputated stumps between the bone and the soft tissues has been noted in amputations in children This has resulted in the skin being tightly stretched over the end of the bone due to increased bone growth, and has given rise to a painful stump Particularly in the upper tibial and lower femoral epiphyses have we noted this complication so that at present in these cases we are careful to fuse these epiphyses at the time of the original amputation or shortly thereafter This point was originally pointed out by vom Saal

The development of painful spurs on the end of the bone may require a re amputation A number of patients first complain of pain at this point following the wearing of a prosthesis, and x rays will reveal the spur formation about the bone end which warrants operation This complication usually means that, at the time of the amputation, sufficient care was not exercised in exposing and retracting the tissues, for undoubtedly careless handling of the periosteum will give rise to spur formation on the bone ends Unless a periosteal cuff about the end of the bone is removed at the time of the amputation, the stump is prone to develop exostoses and spurs under the normal trauma of weight bearing Injection of 95 per cent alcohol into the nerve stumps lessens the probability of neuroma developing, and this injection should be routinely done These neuromata produce bulbous swellings at the end of the nerves and can be very painful, necessitating subsequent exploration and excision

Vascular occlusion or arteriosclerotic gangrene, in which the amputation is done below the limits of healthy skin, will result in necrosis and retraction of the tissues We are using histamine flare injections as described in Part 1, and these injections are applied at various levels on the extremity to determine the suitable area for amputation An area of erythema less than one inch in diameter five minutes after injection is considered to be evidence of inadequate blood supply at that level

Disregard for Site of Election Another frequent cause for re amputation is disregard for the sites of election, and unless there are definite individual reasons, these sites of election should be rigorously ad-

hered to This is discussed in detail in Part I Because a long fibula is so frequently the cause for re-amputation in short leg stumps, it should again be emphasized that in leg stumps less than five inches in length it is best to excise the whole fibula at the time of the original amputation

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Amputations in Diabetes and Vascular Disease

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INTRODUCTION

It is the purpose of this chapter to discuss major and minor amputations in chronic obliterative arterial disease of the lower extremities It will include, therefore, the various aspects of the problem in relation to the following conditions (1) Peripheral arteriosclerosis in both the diabetic (diabetic gangrene) and the nondiabetic (senile gangrene), and (2) thrombo-angutis obliterans

Most of the discussion to follow is applicable to all of the three groups However, the reaction to infection and the indications for amputation in patients with diabetes mellitus are so different from those in patients with thrombo angutis obliterans that certain aspects must be considered separately *Moreover, it would seem imperative* to review the major points in the differential diagnosis of these conditions These will be summarized in a subsequent paragraph

Emphasis will be placed on the lesions occurring in patients with diabetes mellitus, not only because they are the most common ones but also because they are the most difficult to treat successfully

In the diabetic we cannot limit ourselves to the consideration of patients with advanced arterial disease, but must also include those with infection who have little or no impairment of their arterial circulation This group is particularly important since, when properly managed, its mortality should be low and amputation above the midmetatarsal region rarely necessary

GENERAL CONSIDERATIONS

In treating a patient with impending or actual gangrene of a lower extremity, the surgeon must recognize that in both thrombo-angutis obliterans and senile gangrene (more particularly in the latter), the peripheral lesion is but a manifestation of a generalized vascular process, and that the arteriosclerotic patient with gangrene of a toe in all probability has obliterative disease of his coronary and cerebral vessels, and that therefore sudden death from a coronary occlusion may and actually does occur with disturbing frequency The strain of prolonged and continuous pain in the hope of avoiding amputation may well be the precipitating factor in such an accident

An understanding of the many problems these patients present and an extensive experience in their management would seem

to justify the following important principles essential to the successful treatment of these cases

1 Careful preoperative study and management both medically and surgically

2 Avoidance of unnecessary delay in selection and performance of proper type of amputation

3 Well planned and meticulous operative technic

4 Early recognition of surgical complications especially that of spreading or undrained infection in operated foot or stump

5 Continued general treatment and supervision of unoperated extremity to avoid development of lesions which might precipitate need for amputation of remaining foot

DIFFERENTIAL DIAGNOSIS

Arteriosclerotic Gangrene Arteriosclerotic gangrene with and without diabetes may occur in either male or female The symptoms are usually of short duration and very rarely seen below the age of 40 only occasionally between 40 and 50, frequently between 50 and 60 the average age of the patients being approximately 67 years Definite calcification of the vessels by x ray will be present in 70 per cent or more of these patients but may not be demonstrable particularly in the absence of diabetes

A diagnosis of diabetes mellitus is made upon a patient with glycosuria whose venous blood sugar on an unrestricted diet is 0 13 per cent or more fasting or 0 17 per cent or more after a meal [1] [blood sugars of 130 and 170 respectively —Ed] Since we have seen no case of thrombo angiitis obliterans associated with diabetes at either the Massachusetts General Hospital or the New England Deaconess Hospital, for practical purposes one can assume that gangrene in the presence of diabetes is not due to thrombo-angiitis obliterans

Thrombo angiitis Obliterans This is primarily a disease of young and middle aged men In 112 cases admitted to the Massachusetts General Hospital there has been no proved case occurring in a woman The average age of these patients has been *39 years, with an average duration of symptoms of 2 7 years* It is only occasionally seen in patients over 50 years of age, though it may occur in the older age group Calcification of the vessels by x ray was demonstrable in only 10 per cent of the cases studied and in these cases the calcification was only slight in amount Migrating phlebitis involving the superficial veins may or may not be present It is then primarily a disease of young and middle aged men with symptoms of long duration and with little or no calcification of the arteries demonstrable by x ray It usually involves one or both lower extremities but not infrequently becomes quadrilateral

AMPUTATION IN ARTERIOSCLEROSIS DIABETIC

Amputations in so-called diabetic gangrene make up a large proportion of all operations in any active diabetic clinic It is also true that lesions of the lower extremities are one of the most important causes of death in diabetic patients now that coma has its specific antidote insulin

The diabetic has always been a difficult surgical problem because of his increased susceptibility to infection a factor which, when associated with arterial deficiency of an extremity, often creates a situation in which amputation is necessary as a life-saving measure The tendency of infection to extend and the real danger of septicemia and death if prompt surgical measures are not taken, is the most pressing problem that confronts one in the care of these patients Diabetics stand long continued sepsis poorly, both in general and in respect to the diabetes itself Consequently cardiovascular and urinary tract complications often occur in patients with a chronically infected foot

The importance of adequate medical treatment of the diabetes itself is self-evident and must go hand in hand with the surgical treatment Close cooperation be-

tween the medical and surgical sides is essential Formerly it was a common misconception that surgical procedures should not be undertaken in the presence of uncontrolled diabetes This often led to fatal delay in operation It is now well recognized that the diabetes cannot be completely controlled under these conditions until the acute infection has been eliminated It must therefore be the responsibility of the surgeon to decide when amputation is indicated regardless of the diabetic state if the infection is so acute as to make delay dangerous This applies, of course, to the patient with the acute ascending type of infection or to the patient who already has a general septicemia. In many instances in which gangrene or a fairly well localized infection is present immediate amputation is both unnecessary and harmful Here there may be a real opportunity for improvement of the patient as an operative risk, in regard to both his diabetes and his general condition In this type of case the surgeon must be in constant touch with the internist, in order that the patient may have the benefit of a combined opinion as to the optimum time for operation The same close cooperation is essential in the postperative period when, as noted above, complications secondary to general vascular disease are not uncommon

Another characteristic of the diabetic group must be mentioned Arteriosclerosis tends to occur at an earlier age than in the nondiabetic arteriosclerotic It is true also, however, that the diabetic seems to have a greater tendency to develop collateral circulation, possibly because of the longer duration of his obliterative arterial disease or possibly because much of the earlier pathologic process in his arteries is in the intima, with the result that gradual obliteration occurs, rather than the more sudden massive thrombotic occlusion It is not uncommon to find that a diabetic has developed such a rich collateral circulation that he is active and symptom free even though he has no palpable peripheral pulses below the groin It is important to remember, however, that collateral circulation which will sustain a given foot in the normal routine may be inadequate to withstand an extensive infection or an operative procedure involving the deeper structures of the foot

In studying or reporting lesions of the lower extremities in diabetic patients it is of utmost importance to consider those lesions due primarily to a deficient arterial supply separately from those where the arterial supply is adequate and the problem is *primarily one of infection* However, since the discussion which follows is chiefly related to the indications for and the technic of amputation, and since the indications for and the level of amputation are dependent both on the extent of the infection and on the circulatory possibilities of the foot, it will be to consider them together

Preoperative Management of Diabetes

In treating the diabetic patient we must remember not only that (1) he has diabetes, but also that (2) he has had a metabolic disease for one or more years, (3) that he probably has widespread cardiovascular disease, (4) that he is undernourished, (5) that his protein, glycogen, vitamin, and other reserves may be badly depleted, and *(6) that in addition to correction of his carbohydrate* intolerance every effort must be made to improve his general condition so far as possible

Most patients entering the hospital with gangrene or infection will have an uncontrolled diabetes It will probably be impossible completely to control the metabolic disturbance in these patients, and no attempt should be made to obtain and maintain a normal blood sugar Whenever possible the diabetic patient should go to the operating room well fed, with his liver well stocked with glycogen and his urine without acid and with little or no sugar Whereas the diacetic acid can and should be readily eliminated by insulin and carbohydrates, it

may be difficult and even dangerous to attempt to render the urine sugar free by large doses of insulin in the presence of undrained infection

Diet and Fluids In the untreated or uncontrolled diabetic patient any sudden or rapid restriction of diet especially carbohydrate may be disastrous Acidosis, disturbance of the hepatic function and even anuria have been so produced A carbohydrate intake of 125 to 150 Gm a protein equivalent to 0 8 or 1 0 Gm per kg of body weight and fat to a total caloric intake of approximately 1 500 calories should be given daily The diet should be simple and nourishing and supplemented in most instances by additional vitamins particularly A C D and the B complex

If the mouth intake of carbohydrate is inadequate parenteral administration should be used in the form of 5 per cent glucose in normal saline or distilled water intravenously or 2 5 per cent glucose in saline by hypodermoclysis Fluid intake should be adequate to insure an output of 1 500 cc daily if possible However we believe fluids in excess of 3 000 cc per day may be dangerous to the elderly patient with bad cardiovascular disease Moreover we are careful not to give in excess of 30 Gm of salt per day unless there is a chloride deficiency or unless there is loss of chlorides by diarrhea excessive perspiration or vomiting

It was formerly our custom to give nourishing fluids to within four hours of operation Experience showed that in many instances this fluid was later vomited by the patient either at the time of operation or directly following and that it could not be depended upon to increase the glycogen reserve It was therefore discontinued so that now no nourishing fluids are ever given within six hours and only rarely within 12 hours of operation We do not routinely give either hypodermoclysis or intravenous fluid on the morning of operation

Insulin If the patient has been taking insulin prior to admission to the hospital he is given amounts comparable to the usual requirement The doses however may be smaller and at more frequent intervals If the patient has been taking regular insulin no attempt is made to change to protamine insulin before operation although on the morning of operation a dose of protamine zinc insulin is frequently given because of its long continued action which is excellent protection during the entire operative and early postoperative period One half to two thirds of the usual dose of insulin should be given on the morning of operation If the patient has been taking protamine zinc insulin it should be supplemented by regular insulin as needed Small doses given every three or four hours are safer than large doses at longer intervals

Postoperative Management of Diabetes

Diet and Fluids The fluid intake subsequent to operation is comparable to that used in the preparation of the patient for surgery

Except when the nature of the operation requires special dietary regulation liquids such as oatmeal gruel made with water hot tea or coffee (with crackers or toast) are given freely Gingerale and orange juice with egg white are given sparingly on the day after operation One hundred to 150 Gm of carbohydrate are given daily, that amount not taken by mouth being given by supplementary parenteral administration The average postoperative diet of 10 recent patients after amputation of a leg at the New England Deaconess Hospital was 150 Gm of carbohydrate 70 Gm of protein and 90 Gm of fat

Insulin The rapidly acting crystalline insulin and the more slowly acting protamine zinc insulin are potent drugs essential to the safety of diabetic patients but at the same time dangerous unless fully understood and carefully handled

Nurses house officers and doctors must

be constantly alert to insulin reactions Characteristic symptoms of weakness, hunger, nervousness, sweating, and pallor may be absent or masked by other symptoms of the patient s surgical condition Any sudden change in the patient's physical or mental state may be a symptom of hypoglycemia that necessitates an accurate diagnosis Blood should be taken immediately so that the level of blood sugar may be determined Intravenous infusion of 10 per cent glucose may be started at once, to be continued or discontinued depending upon the level of blood sugar as reported by the laboratory It is important to realize that diabetic coma is more easily avoided than insulin shock, that normal repair of the wound will take place with a decreasing amount of sugar in the urine, even though the blood sugar may remain as high as 180 or 200 Mg per 100 cc for four or five days after operation, and that no attempt need be made to render the urine free of sugar in the early postoperative course of the patient

At the New England Deaconess Hospital the routine postoperative insulin orders are

1 Test the urine (Benedict s test) every four hours
2 Give insulin (crystalline) 15 units if the reaction is red 10 units if yellow, and 5 units if yellow green

As soon as the patient can take his usual amount of food, the dose of protamine zinc insulin may be returned to its preoperative level, with the addition of crystalline insulin in accordance with the results obtained The determinations for the blood sugar value should be made as soon as the urine becomes sugar free In this connection it must be remembered that removal of a badly infected foot will rapidly increase the carbohydrate tolerance of the patient and correspondingly decrease the insulin requirement

Comment Paralysis of the bladder, particularly in elderly diabetic patients, is by no means uncommon and is often without symptoms In the case of such a patient, therefore, the result of a test of urine not obtained by catheter may not represent the true excretion of sugar at that time but rather that in the accumulated urine of some hours before A red reaction thus may lead to unnecessary administration of insulin and serious hypoglycemia

Patients with active acute infectious processes which may go on for days, for example carbuncles or infections of the extremities, may require increase of the dose of insulin to as much as 100 to 150 units per day Then suddenly, after drainage of the carbuncle or amputation of the limb, the patient's tolerance may rapidly improve, with the result that if the high dose has been continued serious hypoglycemia will occur For this reason it is our practice in surgical conditions such as these not only to make a quantitative determination of the concentration of sugar in the 24 hour specimen of urine, but, in addition, to test single specimens at two-hour intervals during the day so that a continuous picture of the sugar excretion is obtained Thus if the patient suddenly begins to excrete specimens free of sugar, the dose of insulin immediately can be omitted

The administration of dextrose solution intravenously as a means of feeding the diabetic patient after operation is of great value, but hypoglycemia develops easily if insulin is administered at the same time as the dextrose Also, if insulin is administered according to the amount of sugar in the first urine voided after administration of intravenous dextrose, hypoglycemic reaction will frequently occur A good practice is to give a small dose of insulin, depending upon the amount of sugar in the urine just before dextrose is given intravenously No insulin is given in an attempt to utilize the dextrose about to be administered The patient is encouraged to void two hours after the injection has been completed The urine will in all probability contain a large amount of sugar If insulin is given depending upon the amount of sugar contained in this speci

men, the level of blood sugar may be falling in response to the stimulation produced by the dextrose solution and a serious hypoglycemia may result We therefore disregard this specimen If any subsequent specimens of urine contain sugar, however, the usual order for insulin may be safely followed

Minor Amputation

Definition By minor amputation we mean amputation of all or part of one or more toes with or without excision of the metatarsophalangeal joint Minor amputations are of two types i e open or closed The Lisfranc, Chopart and Symes amputations will not be discussed since they have no place in the surgical treatment of the diabetic nor in the treatment of chronic obliterative arterial disease in general

Discussion Many times the surgeon can be almost certain that a minor amputation will be successful in a given diabetic patient barring some unforeseen complication In many other instances there is much less certainty and the outcome can be determined only by trial However it is essential in these cases that the removal of a digit does not precipitate a rapidly ascending infection or a septicemia In other words it is important to know when amputation of a toe may be done with reasonable safety to the patient even though the outcome is uncertain There are also instances in which amputation of a digit will not only be unsuccessful, but may jeopardize the life of the patient In these cases of course, such an operation is contraindicated

Prognosis Amputation of one or more digits will usually be successful in the absence of gangrene or spreading infection in a foot (1) with good pulsation in the dorsalis pedis artery (2) which is warm, and (3) of good color and good nutrition The color should remain good whether the foot is elevated or dependent

It will also usually be safe if (1) gangrene is limited to the distal half of the toe, (2) there is no level of abrupt color or temperature change with the foot dependent, (3) there is no lymphangitis and any infection which may be present is localized and (4) pain is absent

Contraindications Minor amputation is dangerous and contraindicated in the presence of (1) gangrene of all of a toe in the absence of good pulsation in the dorsalis pedis artery (2) gangrene with lymphangitis, or (3) gangrene or osteomyelitis in a cold, pulseless foot which remains painful after three weeks of careful hospital treatment

Indications Amputation of one or more toes is indicated in the following instances

1 For osteomyelitis involving a phalanx an interphalangeal joint or a metatarsophalangeal joint in a foot with good pulsation in the dorsalis pedis artery or in a foot dependent upon collateral circulation where the foot is well nourished warm and of good color whether elevated or dependent

2 For gangrene of all or part of a toe in the presence of good dorsalis pedis pulsation

3 For persistent or recurrent infection in the toe of a foot with good circulation

4 To secure more complete drainage in cases of infection between the toes or involving the deeper structures of the foot

5 For certain cases of gangrene limited to the tip of a toe, where there is no pulsation in the dorsalis pedis artery and the foot is of only fair color—i e., when there are definite signs of arterial deficiency but acute infection is absent and the patient is not having pain

6 As a prophylactic measure in certain patients who have recurrent or persistent callus formation in a rigid or deformed toe This frequently occurs after the great toe has been removed and when the remaining toes lack normal flexibility In certain of these cases a callus and subsequent ulceration may appear on the most prominent toe In certain other instances a rigid great toe will frequently develop ulceration in a cal

lus along the medial aspect near the tip In these patients a carefully done amputation of one or more (sometimes all) of the toes may prevent serious infection and possibly loss of the foot.

Preoperative Care of Extremities The following points apply to all types of chronic obliterative arterial disease Attention to them and to many other details is essential in the proper evaluation of the patient and the proper preparation for whatever operative procedure may be indicated The most important of the preoperative requirements are

1 Careful examination and evaluation of the circulatory status of the extremity and the extent of the infection or gangrene This includes an x ray to determine the presence or extent of osteomyelitis culture of the local lesion and blood culture if the infection is acute or if there is fever or a history of chills If a beta hemolytic streptococcus is cultured sulfanilamide should be given in adequate dosage and continued according to the accepted method [See Chapter 22 for dosages and modes of administration —Ed] Pure cultures of any organism are unusual Many different organisms are frequently present streptococcus colon bacillus and *Staphylococcus aureus* being the predominating organisms Sulfapyridine does not seem to be helpful in these infections Our experience with sulfathiazole is limited but we have seen toxic symptoms in two elderly patients which makes us feel that it is too toxic a drug to use in these patients unless there is some specific indication for it such as (a) spreading local infection due to *Staphylococcus aureus* or (b) a septicemia due to this same organism (See Chemotherapy Chapter 22)

Careful investigation with a small probe of a sinus near the tip of the phalanx or an interphalangeal joint may detect bare bone and demonstrate the presence of an osteomyelitis before x ray evidence can be obtained It should be noted here that in many of the more extensive infections in diabetic feet gas will frequently be found in the tissues While the presence of gas should always suggest the possibility of infection by one of the organisms of the gas bacillus group, it is most commonly secondary to a mixed infection in the diabetic foot It has no great clinical significance but gas bacillus must be excluded by immediate smear and anaerobic culture

2 If a cellulitis or lymphangitis is present an attempt to check or localize this must be made by the use of moist heat in the form of hot compresses applied to the entire area involved Great care must be taken to avoid burns especially in the diabetic The compresses should not exceed a temperature of 135° and the skin must be protected with vaseline We recognize that in patients with marked arterial deficiency heat may precipitate or increase gangrene However localization of infection is so important in these patients that we believe the advantages of carefully given moist heat are greater than the dangers of producing or increasing gangrene

3 Early drainage of any local collection of pus should be done in conjunction with the treatment as outlined above This is extremely important in the preoperative period in that it helps the acute infection to subside and in many instances makes possible a later minor amputation, whereas undrained the deeper structures of the foot may become so involved as to necessitate its removal Removing part of a callus in which there is a sinus communicating with an osteomyelitis of a joint may be sufficient to improve drainage Removal of all or part of a nail may be helpful when there is a subungual infection with involvement of the terminal phalanx Subcutaneous collections of pus between or at the base of the toes should be drained for the same reason An attempt should be made in each case to make the drainage dependent and the incision adequate enough to lay open the entire broken-down subcutaneous area

In the diabetic, as stated before, these

minor procedures can usually be done in the patient's bed without an anesthetic This does not apply in the cases with poor circulation nor in senile gangrene or thrombo angiitis obliterans Local novocaine when necessary should be used with caution and only when superficial collections of pus are to be drained Adrenalin must not be included Digital nerve block should never be used in patients with obliterative arterial disease, nor should a tourniquet be employed

Preoperative Medication This is unnecessary and may be dangerous if given to the elderly diabetic before amputation under spinal anesthesia These patients are easily depressed by drugs and therefore even a small dose of a narcotic or sedative in combination with spinal anesthesia and operation may be hazardous Morphine and atropine in small doses are given preoperatively to those receiving a general anesthetic

Anesthesia SPINAL PROCAINE HYDROCHLORIDE is the anesthetic of choice in a diabetic having either a major or minor amputation Since the operation is of short duration, the dose should be small and the level of anesthesia kept low Fifty to 75 Mg in 2 cc of either sterile water or spinal fluid are injected at the level of the fourth or fifth lumbar space The table remains level unless a fall in blood pressure occurs A significant drop in blood pressure is dangerous in these patients with cardiovascular disease and may be the predisposing factor to a fatal coronary thrombosis It should not occur with the above technic One ampule (1 cc) of ephedrine given immediately before spinal anesthesia is an additional safeguard against it

GENERAL ANESTHETICS General anesthetics such as nitrous oxide, ethylene, or cyclopropane oxygen may be given in the younger controlled diabetics Ether should be avoided because of its greater tendency to produce acidosis We feel strongly that for operation on a lower extremity spinal procaine is safer than any general anesthetic in the older group if the proper precautions are taken

REFRIGERATION ANESTHESIA The local hibernation of an extremity by refrigeration has been established as practical and useful Its place in medicine and surgery as yet has not been completely evaluated The importance of refrigeration anesthesia in obliterative vascular disease, however, is still more uncertain

There are many factors involved in the total mortality following amputation for gangrene, and to place undue emphasis upon any one factor in improving results following operation may easily result in erroneous conclusions

At the Massachusetts General Hospital on the Peripheral Vascular Service refrigeration anesthesia has been tried in a few selected cases, but has been discontinued because it offered no advantages over the standard procedures now in use

At the New England Deaconess Hospital spinal anesthesia has proved so completely satisfactory and its technic has been learned so easily that refrigeration anesthesia has not been employed In 1941 42 major amputations were done (all diabetic patients) with one death a mortality of 2 4 per cent In 1942, there were 44 amputations with four deaths, a mortality of 9 1 per cent The overall mortality in the 86 operations during the past two years was 5 8 per cent

[The use of refrigeration preceding and after operation in amputations for diabetic and arteriosclerotic gangrene has received considerable attention in the last few years The author of this chapter has indicated his attitude toward its use There are those whose reaction is favorable The Editor is appending a brief description of the claims of its proponents, and an outline of the method, together with some references for those interested in further details

The proponents of the method claim a relatively shockless procedure with no loss of blood, a minimum of preoperative and postoperative pain, the saving of a greater

portion of the extremity by preoperative refrigeration over a period of days than would otherwise be possible and the minimizing of the effects of infection by pre and postoperative refrigeration They state definitely that no limb has been saved which otherwise would have been lost, but that the level of amputation has been affected, and that the healing ability of tissues with poor circulation is enhanced by bringing the tissue metabolic demands down to the level of the impaired circulation s powers to meet them and by interfering materially with bacterial growth and spread

The following extract is an abstract of the method prepared by Frederick M Allen and Lyman W Crossman (See references at end of abstract p 567)—Ed]

REFRIGERATION ANESTHESIA FOR EXTREMITY SURGERY

Frederick M Allen
and
Lyman Weeks Crossman

In response to many requests for the specific details of technic both as to the application of the tourniquet and the method of applying the ice, this outline has been prepared The anesthesia has been complete in our experience and failure to obtain it is because of error in the application of the tourniquet or because the part has not been continuously refrigerated, or both Most of our experience has been with gangrene—diabetic or arteriosclerotic or both—in the aged of the [N Y] City hospital

No drug is necessary as an aid to anesthesia, but anyone about to have an amputation of a leg suffers preoperative emotional distress and should be given a strong sedative

Plan details such as the proposed site for the stump end, the level of the sawline, and the position of the tourniquet The tourniquet must be far enough away from the operative field to allow the surgeon freedom of motion Sometimes it is convenient to mark the skin with stain, thus indicating the three levels

Ischemia. If icebags surround the leg for a half hour at the proposed level of the tourniquet the tissues are numbed so that the application of the tourniquet is not painful Elevate the foot to drain the blood from the extremity Sometimes an Esmarch bandage is applied from the distal tip of the extremity to well above the level determined for the tourniquet If an infection is present in the foot neither the elevation nor the Esmarch bandage would be used

Tourniquet Immediately before the tourniquet is applied and while the foot is still elevated, unwind the Esmarch bandage from the tip until the tourniquet line is reached, apply the tourniquet using a half inch gum rubber tubing, wind it about the leg tight enough to cut off all circulation and re-inforce the ligation by means of a second turn of the tubing about the part, superimposing it on the first application

This makes the line of constriction about a half inch in diameter Clamp the tubing with a strong instrument so that it cannot slip

Refrigerate immediately by placing a layer of cracked ice on a rubber sheeting, the leg on the ice, and covering the entire extremity with ice from one or two inches proximal to the tourniquet down to the toes Wrap the rubber sheeting around the iced leg Cover this with a blanket

If the amputation is to be below the knee and the patient is strong enough to be propped up in a chair, a simpler method is to use a tall pail, fill it with ice and water, and place the foot and leg into it

Our experience has shown that a low or midthigh amputation requires 2½ hours of refrigeration with a tourniquet, 2 hours for the upper third of the leg, 1½ hours for a low leg and an hour for toes or metatarsal amputation

The ice is not removed until the patient has been placed on the operating table The complete surgical team must be ready and waiting for the patient before the refrigeration is stopped by the removal of the ice

In the Operating Room The leg is quickly dried without rubbing, prepared as desired, and the operation performed Do not remove the tourniquet until all the vessels and nerves have been properly treated and the stump is ready for closing The oozing is controlled after the removal of the tourniquet No drain is used unless an infection is suspected A silk technic is used throughout, for ligatures as well as sutures The operator works in a shockless and bloodless field Record of the pulse and blood pressure, taken every five minutes, will show no embarrassment Sometimes when the nerve is cut or the bone sawed, the pulse and blood pressure may be slightly increased but has returned to the previous level at the next five-minute reading

Postoperative After the application of a light but snug bandage the part is placed on a posterior molded plaster splint and the stump surrounded with three icebags for 48 or 72 hours Sutures are removed about the twelfth day

Meals There is no modification of the diet If the trays are served during the period of refrigeration, the patient satisfies his appetite, as he does when the meals are served after the operation

Miscellaneous Suggestions Some patients have been sitting up in bed because of a poor heart and to make them lie down flat on the operating table would cause unnecessary physical embarrassment and it might even be impossible—those patients are operated upon while they sit up

Some have an ankylosis at the knee making it necessary to build a mound of snow ice to conform with the angulation and insure a continuous refrigeration at the popliteal space

Midthigh amputations for gangrene of the leg, even when there is a definite cellulitis of the thigh, have not been found necessary We prefer a low amputation even if the stump is left wide open

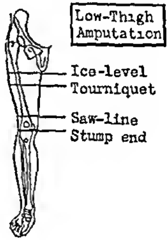
For a low thigh amputation, a rapid preliminary disarticulation at the knee allows the removal from the operating room of the malodorous, infected extremity The surgeon completes the operation working from below, seated at the foot of the table instead of leaning across or stooping to work on the posterior aspect of the thigh

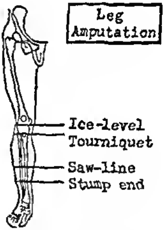
Refrigeration lasts about one hour If the room is warm, or there has been a delay after the ice was removed, or room temperature saline is used for irrigation and moistening of gauze wipes, the part warms up more quickly and the anesthesia period is shortened Chilled saline is used for irrigating and to moisten gauze

The incision does not have to hug the tourniquet The average stump has the tourniquet three to six inches away as there is no reduced vitality of the distal tissues because of the tourniquet

Skin flaps do not slough from refrigeration If the skin edges are cyanotic or there is a slough or a hematoma or an infection, not present before the operation, the surgical technic must be blamed Too much suture tension may cause trouble Relieve tension, and reapply ice bags The reduced temperature slows up metabolism in the part and allows the circulation to recover itself In a day or two, when the local condition has improved, remove the ice

Advantages of Refrigeration Anesthesia In our experience it has saved lives There is no evidence of shock—during or after operation There is no pre or postoperative pain, no gastro intestinal disturbance





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Technic Amputation Through Proximal Phalanx Two methods—(1) closed and (2) open—will be described

closed amputation When there is no open lesion, or when the lesion is so placed that the line of incision does not pass through infection in the skin or a sinus tract, closed amputation is used A small area of gangrene near the tip of the toe or an osteomyelitis of the tip of the phalanx or of an interphalangeal joint are the most common lesions for which this procedure is used

The skin is carefully cleansed with ether and then painted with an efficient but non irritating antiseptic Tincture of metaphen has proved very satisfactory in our experience Strong antiseptics such as tincture of iodine should not be used in the diabetic or in cases of arterial deficiency in general

A racquet incision is used (Fig 471) The position of the incision should be such that the handle of the racquet is the most dependent point This facilitates division of the phalanx and also gives the most satisfactory drainage in the event of postoperative infection It is also important that the handle of the racquet be so placed that it is in line with the incision that would be made should deeper extension of the infection necessitate additional drainage In the case of the second, third, and fourth toes the handle of the racquet is therefore on the

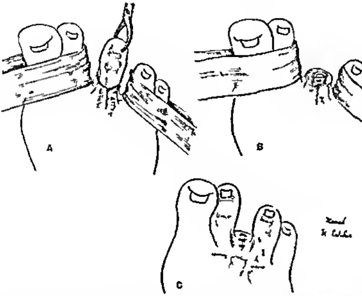


Fig 471 Closed toe amputation (A) A racquet incision is used with most dependent point on dorsum of foot Gentle retraction of adjoining toes is obtained by gauze sponges The toe to be amputated is best handled by grasping with a towel clip (B) Illustrating unsutured incision following amputation Absence of skin flaps minimizes manipulation and conserves blood supply Tendon has been divided with toe in slight flexion so as to avoid retraction upward into sheath (C) Note that proximal phalanx has been divided just distal to proximal head This removes enough phalanx to allow approximation of skin edges without tension It also leaves enough phalanx so that injury to metatarsophalangeal joint is avoided Skin sutures must be minimal in number and give good approximation without undue constriction

dorsum of the foot This may also be the case in amputation of the first or fifth toes when prompt healing would seem assured However, in questionable cases it is usually placed along the medial or the lateral border of the foot respectively Should infection extend to the deeper structures of the foot it can be readily drained through an extension of the incision

The line of incision around the toe varies from 0 5 to 1 0 cm distal to the base of the toe depending upon the diameter of the toe and the proximity of the infection It is important to leave enough skin to allow approximation of the edges without tension The knife used for the skin incision should be discarded and a clean one employed for the remainder of the amputation The tendon sheath and tendon are divided cleanly with the toe in slight flexion so as to prevent retraction of the tendon up its sheath It is neither necessary nor advisable to do anything to the cut tendon or its sheath The tissues in relation to the proximal phalanx are gently incised so as to expose the bone The line of division of the phalanx is just distal to the broad base of the proximal phalanx Rarely when there is no infection and when it is impossible to bring the skin edges together because of the broad base, a disarticulation may be done In these instances no attempt is made to remove the cartilage of the head of the metatarsal This difficulty in closure is rarely encountered except in the great toe It should be clearly stated, however, that *disarticulation should never be done in the presence of active infection* The phalanx is divided with sharp bone cutting forceps Sharp edges of bone, if present, are removed with rongeurs Only rarely will it be necessary to ligate pulsating vessels When this is done No 000 or preferably No 0000 plain catgut is used The skin edges are then loosely but carefully approximated with fine interrupted silk sutures and a dry sterile dressing applied

Throughout the amputation every effort should be made to avoid unnecessary trauma The incision should be clean and decisive The skin edges should be manipulated as little as possible, and sponging with gauze kept to a minimum Successful healing, particularly in cases with reduced circulation, depends upon painstaking technic and rigid asepsis (Figs 472 and 473)

OPEN AMPUTATION This method is restricted to those cases where amputation must be done through an area of infection whether it be in the skin or when the incision has gone across a sinus tract The technic of operation is exactly the same as described above It should be repeated that *disarticulation is never done through an area of infection* Protection of the tendon sheath is important in these cases Great care is taken to cut across the tendon with a clean knife, and to be certain that the tendon is cut slightly longer than the sheath so that there can be no immediate retraction A small piece of dry gauze is placed promptly against the cut tendon and after completion of the operation it is removed and the entire wound packed loosely with dry gauze No other treatment of the tendon or its sheath is indicated There is almost immediate sealing off of the sheath in those cases in which the circulation is adequate If the infection has extended beyond the limits of the toe the incision of amputation is usually directly connected with whatever incisions may be necessary to drain the entire infected region adequately (Fig 474)

The fundamental principles in the management of these infections are wide open drainage, preservation of the blood supply, and the placing of the incision so that its lowest point is the most dependent point of the infected area when the foot is in the normal resting position In cases where there has been extension from the toe into the plantar tendon sheath the incision must be carried onto the plantar aspect of the foot and the tendon sheath opened throughout the course of the infection, the sheath

being opened and the necrotic tendon excised up to, but not beyond, the limits of infection

Here again the sheath should be opened 1 or 2 mm proximal to the line of division of the tendon The skin incision must extend 2 or 3 cm beyond the level at which the sheath is opened

Amputation Through Metatarsal Bone Indications (1) Osteomyelitis of a metatarsophalangeal joint The most common lesion is an infected callus on the plantar aspect of the foot with extension into the joint The first and fifth joints are most commonly involved (2) To insure more adequate drainage of extensive infection deep to the plantar fascia Extension of infection between the metatarsophalangeal joints from a lesion between two toes is an example of this (3) Occasionally for gangrene or infection involving so much of a phalanx that adequate skin cannot be saved to cover over the cut end of the phalanx.

In the diabetic, excellent circulation, including a palpable dorsalis pedis artery, is usually necessary for success in such a radical local procedure However, there is an occasional case with an extraordinarily well developed collateral circulation in which success may result as an exception to this rule Even in these cases, however ultimate healing will be greatly prolonged over the time required in those cases where the blood supply is through larger vessels

Fig 472

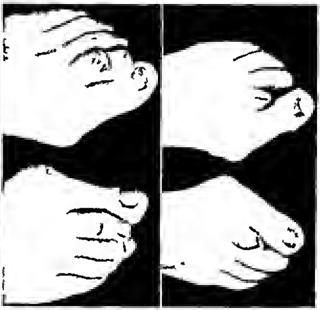


Fig 473

Fig 472 Healed closed amputations of four toes

Fig 473 Prophylactic closed amputations of second toes for recurrent pressure areas due to hammertoe deformity

Technic *Amputation Through First or Fifth Metatarsal* The racquet incision is used, with the handle of the racquet extending along the medial or lateral aspect of the foot respectively (Fig 475) The skin incision will be carried along the side of the foot to well beyond the limits of infection or the line of division of the bone Care should be taken that the incision more

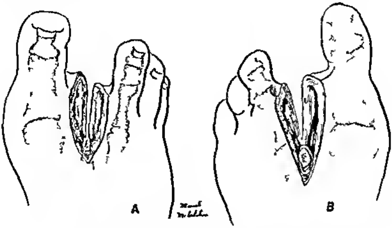


Fig 474 Open amputation of second third, or fourth toe including metatarsophalangeal joint (A) Dorsal surface of foot, illustrating maximum drainage obtained by through and through type of incision Note level of division of metatarsal just proximal to head of bone (B) Plantar surface of foot Note that incision gives completely dependent drainage in relation to metatarsal shaft and flexor tendon sheath Postoperative extension of infection deep into foot along these structures is avoided by this type of incision

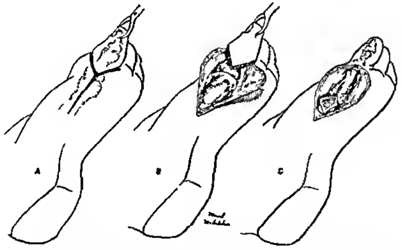


Fig 475 Open amputation of first or fifth toe including metatarsophalangeal joint (A) Racquet incision is placed so that long dependent portion extends along medial and plantar surface of metatarsal (B) Metatarsal is divided in a beveled manner proximal to upper limits of incision (C) Illustrating adequate and dependent drainage resulting following amputation Location and length of skin incision together with beveling of metatarsal shaft minimize possibility of extension upward Note also close proximity of exposed capsule of adjoining metatarsophalangeal joint Great care is necessary to avoid injuring this

nearly approximates the plantar aspect than the dorsal aspect of the metatarsal This is particularly important in order to insure adequate drainage to the subfascial area of the foot should this area be involved by the infection Great care must also be taken with the dissection between the adjacent metatarsal heads This space is extremely narrow and the adjacent uninvolved joint may be easily opened

When the head and the distal shaft of the bone has been dissected free the shaft is divided just proximal to the head with sharp bone forceps The shaft is so beveled that the base of the cavity slants from the inner aspect of the wound downward toward the end of the skin incision The sesamoid bones are removed The flexor tendon sheath and tendon are divided at the upper limits of the infection otherwise at the point where the sheath has been opened

If the adjacent metatarsophalangeal joint is involved it is excised through the same incision This will necessitate removing the bone already divided at a higher level in order that the base of the cavity may be perfectly smooth without any dead space between the two metatarsals As in the case of the head already excised it is extremely important to make certain that the line of division of the bone has been sufficiently high to insure removal of the entire head The cavity is then loosely packed with dry gauze containing one or more Dakin s tubes depending upon the size of the cavity There should be no approximation of skin edges (Fig 476)

Amputation through Second Third or Fourth Metatarsal The incision used may be called a double racquet with one handle extending onto the dorsum and the other directly opposite onto the plantar aspect of the foot It is the latter which becomes the most dependent part of the cavity following operation Care should be taken to extend this incision far enough onto the plantar aspect of the foot to insure uninterrupted direct drainage Here also great care must be taken not to enter the adjacent metatarsophalangeal joints and here again unless one is careful a portion of the cartilage from the head of the bone easily may be left The line of division through the metatarsal must be proximal to the entire head of the bone If necessary one or both of the adjacent metatarsophalangeal joints may be excised through this same incision Gauze and Dakin s tubes are used as above (Fig 477)

FIG 476 Amputation of first metatarsophalangeal joint

FIG 477 (*Left*) Healing amputation of second toe and metatarsophalangeal joint dorsal surface of foot (*Right*) Same case illustrating extension of incision onto plantar surface of foot

Postoperative Care of Minor Amputations Care following closed amputation is simple Unless there is elevation of temperature or postoperative pain or unless the diabetes is not responding as would be expected the dressing need not be done for four or five days at which time some of the

sutures are removed If infection is found, all of the skin sutures must be removed and the edges of the skin separated in an attempt to prevent extension of the infection into the foot. A small piece of gauze kept saturated with Dakin s solution or azochloramid in saline (1 3300) is then used The cautious use of sterile warm moist compresses may be helpful In many instances the patient is encouraged to lie face downward to facilitate dependent drainage If the infection extends in spite of this treatment either more adequate drainage or if the circulation is inadequate early major amputation may be indicated

In open amputations where Dakin s tubes have been incorporated instillations of 5 cc occasionally 10 cc. of Dakin s solution into each tube are begun about four hours after the return of the patient to the ward and repeated every two hours day and night It is of extreme importance in these cases where Dakin s solution is used to protect the normal skin against its irritation For years we have used the solution of one part rubber cement to three parts of ether as recommended by Farr[2] This is first applied to the adjacent skin and over this are placed the strips of sterile compress cloth saturated with vaseline Even with this care the skin may become irritated and it may be necessary to discontinue the Dakin s solution until all evidence of irritation has disappeared

In these wounds the original gauze is usually removed on the third or fourth day A careful daily dressing is then done removing and replacing gauze and tubes Care is taken to avoid any contact of the tubes with joint surface When all sloughing tissue has been removed and when the wound is clean and granulating the tubes are removed A small piece of gauze saturated with azochloramid in saline 1 3300 is then applied daily and the pack moistened three times during the day The edges of the wound are gradually allowed to fall together and when it is too small to contain such a dressing, a codliver oil ointment dressing is most frequently used

The dressing care of these patients is an exacting and time-consuming duty and should be entrusted only to those who are experienced in the surgical care of such cases The surgeon obviously cannot be present to moisten a pack every two hours but he must be able to follow the cases closely enough to detect complications early Multiple operations are often necessary to save an extremity in these patients and therefore frequent examination and dressings by the surgeon are essential

Buerger exercises[3] should be used in conjunction with the surgical care of the foot in all cases with arterial deficiency in an attempt to stimulate circulation They should not be started however until all acute infection has subsided In addition intermittent venous occlusion (Collins and Wilensky[4]) may be helpful

Rapid mobilization of patients who have been in bed for any length of time preceding or following minor amputation must be avoided Even those with good circulation should have a preliminary period of Buerger exercises before becoming ambulatory When the patient is ready to walk it is our custom to have him begin by walking a half a minute every hour for the first day This may be increased to one minute per hour the second day and thereafter a minute per hour each day until the patient can safely move around as desired We have seen neglect of this important principle result in failure of what should have been a successful attempt at saving an extremity It should also be added that when the patient first starts to walk he should not be permitted to sit down between periods of his exercise He should rather go back to bed to avoid the stagnation that accompanies a sitting position whether the foot is allowed to rest on the floor or is elevated on a camp stool

Results In the accompanying table are given the results following minor amputa

tion in 362 diabetic patients admitted to the Deaconess Hospital during the years 1923 to 1940 In order to show the extreme importance of the presence of pulsation in the dorsalis pedis artery or of adequate collateral circulation, these patients are classified according to the adequacy of arterial supply to the foot

Minor Amputation in 362 Diabetic Patients*
(1923–1940)

	Dorsalis Pedis Pulse 0		Dorsalis Pedis Pulse +		Both Groups	
	Cases	*Mortality*	*Cases*	*Mortality*	*Cases*	*Mortality*
Minor amputation only	68	5 9%	227	1 3%	295	2 4%
Minor amputation followed by major amputation	43	9 3%	24	12 5%	67	10 4%
Totals	111	7 2%	251	2 4%	362	3 9%

* From the New England Deaconess Hospital Boston

Major Amputation

Definition A major amputation is one through the long bones of an extremity Only those procedures of proved value in the diabetic clinic at the New England Deaconess Hospital and at the Peripheral Vascular Clinic at the Massachusetts General Hospital will be described in detail These are (1) Guillotine amputation (lower leg and thigh), (2) closed amputation through the lower leg, (3) Gritti Stokes amputation (4) supracondylar amputation In addition to these, two operations have been used with success by other clinics and completeness would demand their inclusion in this discussion They are (1) Closed guillotine type of amputation through the lower leg described by Dr Beverly C Smith of New York, and (2) the tendinoplastic supracondylar amputation of Callander

Indications Extensive Infection of Foot with or without Gangrene This includes those cases, with or without gangrene, where there is extensive infection beneath the plantar fascia, usually with involvement of several metatarsophalangeal joints The carpal bones, or even the ankle joint, may be involved in neglected cases Patients who have had unsuccessful incision and drainage of the foot with or without an associated minor amputation, and whose infection has continued to extend beyond the point where further local procedures are safe or justifiable, are included in this classification Continued sepsis of this type, even though not acute, is a real hazard to the diabetic patient and should not be unduly prolonged Major amputation may be the only means of getting such a patient well If gangrene is present, particularly if there is no pulsation in the dorsalis pedis artery and if there is no satisfactory evidence of healing within two or possibly three weeks following minor amputation, amputation at a higher level should then be done

Acute Fulminating Ascending Infection These cases usually have a high cellulitis or lymphangitis secondary to deep infection of the foot If the infection does not subside after 48 to 72 hours of chemotherapy, hot compresses, and drainage of local collections of pus as previously described, amputation will usually be indicated Any attempt at extensive local operation in the presence of advancing cellulitis or lymphangitis may precipitate a septicemia A local operation in this type of foot is absolutely contraindicated in the absence of bounding pulsation in the dorsalis pedis artery

Septicemia Secondary to Infection of Foot In many instances these patients will

be critically ill on admission to the hospital with extensive infection, fever, and a history of chills In other instances the evidence of septicemia may not be so strong Any patient with gangrene of one or more toes and a temperature out of proportion to the evidence of local infection should be strongly suspected of having a septicemia Septicemia may be precipitated by an ill advised minor amputation in a pulseless foot with gangrene and unsuspected infection

One occasionally obtains a positive blood culture from a patient where the circulation to the foot is excellent and where the local infection is relatively minor We have had one such patient where repeated pure cultures of beta hemolytic streptococcus were obtained from the blood stream who recovered following the use of sulfanilamide and local drainage Experience to date however would suggest that chemotherapy will play a very small part in controlling the deeper infections of the foot so completely as to avoid amputation in these cases

Gangrene of One or More Toes in Absence of Pulsation in Dorsalis Pedis Artery When gangrene has involved all of one or more toes and the gangrene is due to inadequate arterial supply rather than to thrombosis of minor vessels associated with extensive local infection early amputation is indicated

Lymphangitis Secondary to Local Ulceration or an Area of Gangrene in a Pulseless Foot Amputation is indicated if the lymphangitis does not subside under bed rest local warm moist dressings and treatment of the diabetes Local amputation in this group is hazardous and may seriously undermine the general health of the patient as well as deplete the family finances Inadequate circulation increases the risk of delay

Prolonged Chronic Infection of an Extremity The serious effect of long standing infection upon the diabetic, and also the expense of hospital treatment, may make amputation desirable Inadequate circulation in such a foot greatly increases the risk of delay and reduces the already distant possibility of ever obtaining a useful foot

Pain with or without Local Lesions Persistent pain in spite of adequate hospital treatment is one of the most important symptoms associated with arterial deficiency The severity of the pain is often proportional to the degree of obliterative disease There may or may not be an open lesion Any diabetic patient seeking relief of pain in the foot or calf of the legs, which persists when the patient is at rest is in danger of losing the extremity and should be immediately hospitalized for intensive detailed treatment If such a patient is unrelieved of pain after a period of three weeks of hospital treatment consisting of complete rest in bed carefully regulated Buerger exercises intermittent venous occlusion and adequate care of the diabetes, a major amputation is indicated This is in striking contrast to thrombo angiitis obliterans where peripheral nerve block as a means of relieving pain is usually successful

Preoperative Care of Extremity Those points already discussed in the preparation of a patient for minor amputation are equally applicable to the patient in need of a higher amputation The correct preoperative management of these cases is essential not only to a low mortality but also to a satisfactory postoperative convalescence There is an optimum time for and optimum conditions under which a closed major amputation can be most successfully carried out In general operation should be done at the earliest time consistent with safety

In many cases in which gangrene is the indication for amputation there is no acute infection present In these local preoperative measures do not alter the level at which operation should be done nor the type of amputation indicated Many cases however, have acute infection of varying degrees which may be limited to the foot, or may be associated with a cellulitis or a lym

phangitis extending to any level on the extremity It is in these cases particularly that carefully applied hot compresses in conjunction with drainage of local collections of pus in the foot may reduce the level of infection and safely permit a closed amputation rather than an open one This is particularly true where the circulation is poor and where it is characteristically more difficult to control or localize infection We do not hesitate to use moist heat locally in these patients because decision for major amputation has already been made and our primary interest is control of the infection even though the local gangrene may extend Many times painstaking treatment under careful supervision will permit marked improvement in the patient's general condition and sufficient improvement in the local infection to warrant a safe closed amputation when if operation were done earlier or if conservative treatment were continued too long an open operation (i e guillotine amputation) might be necessary as a life saving procedure

Cardinal Principles in Technic of Major Amputation There are many important details in the technic of major amputation which must be observed if successful results are to be obtained They apply to amputations in patients with all types of obliterative arterial disease and will be enumerated and discussed below

Preparation of Operative Field The preoperative preparation of the skin in all amputations deserves special mention It is to be assumed that the skin adjacent to an infected gangrenous foot is badly contaminated with pathogenic organisms of various kinds not infrequently including those of the gas bacillus group It is therefore extremely important that the area of skin to be prepared for any given operative procedure must be restricted to the field of operation and that all manipulation both above and below this region be avoided

The following technic of skin preparation has proved very satisfactory in a large series of cases at the New England Deaconess Hospital On the evening of the day before operation a heavy dressing is placed on the involved foot and held in place by a firm bandage which will serve as an additional precaution against any manipulation in relation to the infected area The operative field is then shaved and thoroughly but gently scrubbed with tincture of green soap and water The limb is shaved approximately 10 cm above and below the proposed line of incision The area which is scrubbed does not exceed 6 cm above and below the incision The entire area is then carefully sponged off with alcohol and finally with ether The entire area which has been shaved is then painted with tincture of metaphen and covered with a sterile towel kept in place with cotton bandage and adhesive

When the patient is on the operating table and ready for draping the sterile dressing is removed and the entire area again painted with tincture of metaphen

Draping of Patient A satisfactory method of draping the patient for amputation greatly facilitates the operation It not only prevents contamination but also insures complete visualization of the field at all times and eliminates any necessity for harmful retraction or other handling of tissues The advantage of this method of draping is that the extremity which is held at all times by one of the operating team may be raised or lowered freely as is necessary during the amputation This unlimited mobility is valuable especially when the surgeon is working posteriorly High elevation with full extension of the knee places muscles nerves and vessels under tension so that they are not only more easily and quickly identified but also fall away after division and need not be retracted at any time (Fig 478)

No Tourniquet A tourniquet should not be used in these cases because of the danger of further injuring vessels in an extremity which already has reduced blood supply

Small but important collateral vessels may be sufficiently damaged by pressure of the tourniquet to become thrombosed. Patent main vessels may be injured to such an extent that thrombosis and occlusion may should and can be avoided, except in the Gritti-Stokes amputation Their use entails added manipulation of tissues which, in the diabetic especially, may reduce the blood supply and the local resistance of the skin

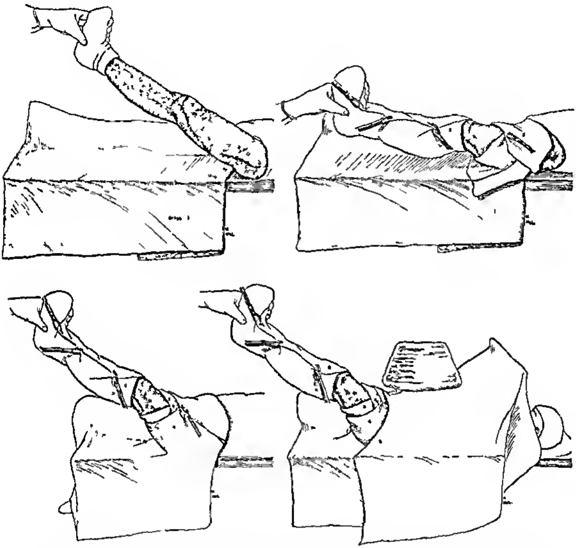


FIG. 478. Method of draping for amputation Order of application of drapes is indicated by numbers 1 to 5. Note that a minimum amount of exposed skin is left in operative field; also that draping allows free manipulation of limb at all times.

later occur. The only exception to this rule is in the lower-leg guillotine amputation, where the possibility of injury to vessels is less important than is a bloodless field permitting a rapid amputation with a minimum of manipulation.

AVOIDANCE OF SKIN FLAPS. Skin flaps and subcutaneous fat. This interferes with first-intention healing and may even result in necrosis of the skin edges or predispose to a secondary infection which would otherwise not have occurred This fact is well borne out by the high percentage of cases with primary healing of thigh amputation

stumps (96 per cent) at the New England Deaconess Hospital These patients were in the poor risk group The amputation which uses a circular incision will be described below

We have seen no difficulties with the scar after the use of the circular incision in either the thigh or lower leg amputations The position of the scar is of less importance than its character General factors concerned in the satisfactory amputation stump are discussed later

A Minimum of Trauma to Tissues A clean, decisive incision and a minimum of manipulation throughout the amputation are essential Excessive handling sponging, or retraction is objectionable and may interfere with healing or increase susceptibility to infection

Avoidance of Contamination from Skin Contamination from the skin is an ever present danger regardless of how carefully it has been prepared Care must be taken to prevent instruments, sutures, or sponges from touching the skin and then being used inside the wound Sponges should be used but once and then discarded

Complete Hemostasis Hemostasis must be complete but attained with a minimum of handling Hematomata present in the stump are excellent culture media and must therefore be avoided

Treatment of Nerves All nerves are crushed, tied at the same level, and then divided and cauterized (with the actual cautery) at a point 2 to 3 mm distal to the tie The maneuver should be done with the nerve under tension so that when released it will retract upward out of the end of the stump The use of the cautery takes less time and is as effective as alcohol injection in the prevention of neuromata The necrosis of the surrounding tissues that may result from leakage of alcohol is avoided by this method

Treatment of Periosteum The periosteum is cut cleanly around the bone with a knife and then scraped away distally Care must be taken not to leave any fragments of periosteum The bone is divided through its denuded area at a distance of 2 mm from the clean-cut periosteal line

Sutures and Ties The size and quantity of suture material and ties must be kept at a minimum in order to insure as little reaction as possible in the tissues of the stump Results are no better using fine silk than with catgut of the proper size In either case, of course, as little tissue as possible should be included in each tie and it should be cut close to the knot

The following sizes of catgut are satisfactory and nothing larger should be used No 00 or 000 plain for all small vessels and all nerves, No 1 chromic for the femoral and popliteal vessels, No 0 chromic for the main vessels of the lower leg, No 00 chromic for suture (interrupted) of muscles and fascia

No Drainage Drainage of an amputation stump is never indicated The stump must be left completely open (as in guillotine amputations) or closed without drainage A drain is a foreign body and can serve only as a means of introducing infection

Preoperative Medication and Anesthesia. These are the same as those for minor amputations

Guillotine Amputation The guillotine amputation may be a life saving procedure in the desperately sick diabetic patient with an acute extending infection of an extremity The value of the operation lies in the fact that by it one can suddenly and completely eliminate the focus responsible for the patient's serious condition In addition, it tends to insure drainage of residual infection in the lymphatics at higher levels in the extremity This two-fold effect makes recovery possible and avoids the often fatal sepsis which may occur in a closed amputation stump under these conditions Its value is obvious in the presence of a definite septicemia, since without it continuous infection or re infection of the blood stream occurs, and any closed amputation will nec

essarily become infected The survival rate in cases of septicemia is small at best, but had been nonexistent without the guillotine amputation Chemotherapy is now available and is a powerful adjunct to operation, but it should not be expected to replace removal of an extensively infected and usually gangrenous foot

Cases which do well after guillotine amputation show an immediate postoperative drop to normal of temperature and pulse Those who do poorly show a continued or recurrent temperature which indicates either another focus of infection septicemia or rarely, extension of infection in the stump Their prognosis is bad

In the successful cases a secondary higher amputation (Gritti Stokes or low thigh) is done when the general condition of the patient has shown sufficient improvement We believe that the lower leg guillotine amputation even if well healed through the use of traction and skin grafts rarely gives a serviceable stump and that therefore the higher secondary amputation is necessary The only exception to this is in the occasional patient who never becomes a reasonably good risk for re amputation or in the young patient in whom amputation is done for infection and the knee joint can be saved

TECHNIC The preoperative skin preparation as described above is modified in that the soap-and water scrub is omitted Such manipulation near an area of acute infection is dangerous and may cause further extension A tourniquet is applied at the mid thigh before the patient is draped This as stated above, is the only amputation in obliterative arterial disease (diabetic or nondiabetic) in which a tourniquet is permissible The amputation is usually done through the middle or upper third of the lower leg, depending upon the fevel of infection It is preferable that the incision be above the level of gross infection, although it may be done safely through an area of lymphangitis If there is massive gross infection to the knee or involvement of the knee joint the amputation must be done through the thigh (see below)

The incision is a circular one the skin, fascia muscles and bones being cleanly divided at the same level The soft tissues retract somewhat as each layer is divided so that the ideal lower leg guillotine stump is slightly conical in shape All visible vessels are clamped and tied after the distal part of the extremity has been removed and before release of the tourniquet

After the tourniquet has been removed, any remaining bleeding vessels are clamped and tied The nerves may be disregarded since the guillotine amputation stump is not a permanent one Care should be taken to control all bleeding before the dressing is applied Throughout the operation all manipulation must be avoided especially in relation to muscles and fascia

The most satisfactory and comfortable dressing consists in a large square of close meshed material (compress cloth) covered with a thin layer of sterile boric or cod liver oil ointment This is applied directly over the open end of the stump A generous dressing of sterile gauze squares or strips and a drainage pad are laid over this and the whole stump bandaged with cotton bandage Two wide adhesive strips placed crosswise over the end of the dressing and onto the skin above keep the dressing in place Adhesive placed in a circular manner around any stump may constrict and should never be used A posterior splint with a small supporting pad under the bend of the knee is then applied This should be long enough to extend from the end of the stump to the fold of the buttocks

If the amputation is done at a level where there is obvious gross infection of the fascia or muscles the ointment dressing should not be used but, instead one containing Dakin s tubes is placed over the end of the stump Dakin s solution can then be instilled into the tubes at regular intervals post operatively This type of dressing is much

more uncomfortable and more difficult to manage than the ointment type described above, but may occasionally be necessary

Essentially the same technic is used in the thigh guillotine amputation as that described later under thigh amputation No tourniquet is used and it is permissible to divide the femur above the level of the skin incision This can be done in the thigh with little or no manipulation of soft parts (in contrast to the lower leg) and makes it possible later with the use of traction to pull the skin down over the end of the bone to facilitate healing The nerves and vessels are treated in the usual manner The same type of dressing is applied as in the lower leg guillotine amputation, including a posterior splint for immobilization

In any guillotine amputation it may be necessary to make longitudinal incisions from the end of the stump upward to lay open any areas of gross infection discovered at the time of operation If this is not done further extension may occur

Lower leg Amputation There is no question that the lower leg amputation is more satisfactory from the point of view of efficiency and ease in walking with an artificial leg than any other type of major amputation The preservation of the patient's knee joint is of course responsible for this Unfortunately, however, it has definite and very important disadvantages which often outweigh its benefits and make it necessary to consider many factors in the selection of suitable cases

Indications The surgical requirements for a lower leg amputation are (1) Adequate circulation (as evidenced by a palpable popliteal artery pulsation and a warm skin of good texture with no abnormal color changes above the level of the ankle), and (2) absence of infection (i e, no septicemia), and no lymphangitis phlebitis, or cellulitis above the level of the ankle

If both the above requirements are met, the amputation is indicated in patients who are under 60 years of age, light or average in weight (never overweight), and active but not required to stand for long periods of time

Disadvantages The disadvantages of the lower leg amputation are three

IMMEDIATE POSTOPERATIVE COMPLICATIONS The most important of these is delayed healing Areas of necrosis in relation to the skin edges are not uncommon and may be due to a combination of factors such as minor infection, thin vulnerable skin, and diabetes Even with careful operative technic a certain amount of manipulation is unavoidable in the lower leg amputation This contributes to the delayed healing and the often prolonged hospitalization

GANGRENE OF STUMP This may occur in cases with advanced or rapidly progressing arterial disease The elderly diabetic may have such a process, resulting in a popliteal or femoral artery thrombosis If this occurs in the same extremity, gangrene of the stump will result. It may appear weeks, months, or years after the amputation and necessitates a secondary thigh amputation It is therefore preferable to select younger patients with good circulation for lower leg amputation

TENDENCY TO PRESSURE AREAS OR ULCERATION The stump is of necessity subject to lateral and medial pressure since weight bearing is received in these areas through the artificial leg Constant pressure at these points in patients doing a considerable amount of walking leads to stump difficulties in many instances Therefore patients who wish to do much walking or who are overweight are not suitable for this type of amputation.

It naturally follows from what has been said that proper fitting of the artificial leg is essential and that frequent adjustments are necessary in patients with this type of amputation stump A conscientious and interested limb maker should be constantly available to the patient if trouble with the stump is to be minimal

Technic The level of the incision can

not be fixed but must vary, depending upon the adequacy of the circulation and the level of infection in the individual case. It is rarely that a lower-leg stump can be safely obtained that is longer than four to six inches as measured from the tibial tubercle. Stumps as short as two inches may be perfectly satisfactory, however, while no lower-leg stump should exceed eight to nine inches in length.

The type of incision used should be one that minimizes the length of the skin flaps, but yet favors the performance of the amputation with a minimum of trauma We have used and discarded the common types of incision—i e, circular, lateral-medial flaps, and anterior-posterior flaps—and now employ a simple racquet incision This seems best to meet the above requirements. The handle of the racquet is placed laterally and extended upward along the shaft of the fibula for a distance of two inches.

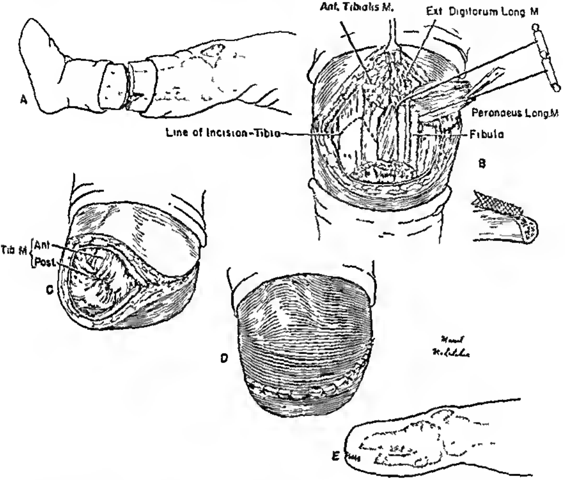


FIG. 479. Lower-leg amputation. (A) Level of racquet incision. Note extension upward along shaft of fibula. (B) Skin, fascia, and muscles have been divided, exposing tibia and fibula. Note difference in the level of division of bones and beveling of tibia. (See inset for further beveling with file) (C) Approximation of muscle layers has been done and the more important approximation of the anterior and posterior fascia has been started Lack of tension in all layers is of utmost importance. (D) Skin has been approximated carefully without tension. (E) Proper difference in lengths of tibia and fibula in closed stump.

Fig 480

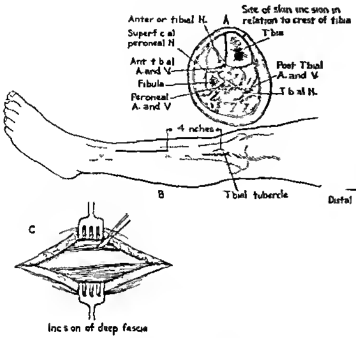
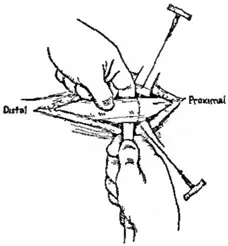


Fig 481



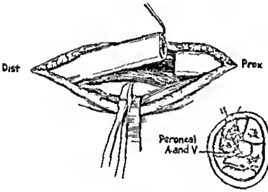


Fig 482

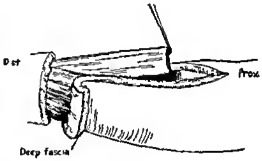


Fig 483

Fig 480 Beginning four inches below tibial tubercle, a skin incision along middle of anteromedial surface of tibia is carried down to periosteum and distally for six inches (A) Shows relation of skin incision to anteromedial surface of tibia (B) Fascia adjacent to both sides of tibia is incised the length of the skin incision

An instrument or the finger is then placed in the avascular area on both sides of tibia between it and the muscles, and by sweeping finger along first one and then the other side of tibia for extent of incision, it is separated from the investing muscles down to interosseous membrane

Fig 481 Interosseous membrane is pierced with a sharp periosteal elevator which is carried distally and proximally, freeing tibia from this structure for extent of incision A Gigli saw is passed posterior to tibia at upper angle of wound in jaws of a curved clamp and is grasped with a clamp on opposite side, pulled through, and the handles placed on the saw Soft parts are protected from saw by medium abdominal retractors Tibia is divided with Gigli saw as water is dripped upon site of division Care is taken to prevent injury to soft parts, particularly posterior tibial vessels

(Continued on next page)

This simplifies the high division of the fibula and consequently helps to reduce the considerable amount of trauma often associated with this step of the operation (Fig 479).

The incision is carried through skin and fascia, the latter being separated from the anterior aspect of the tibia by sharp dissection The knife should be changed after the skin incision The muscles are divided cleanly (with a minimum of trauma) down to the bones, all main vessels and nerves being identified and clamped before being cut The interosseous membrane is divided last The muscles are dissected free along the shafts of the tibia and fibula up to the proper level This distance is approximately half of the diameter of the lower leg and is measured on the tibia from the level of the skin incision The fibula must be divided at a level at least an inch higher than the tibia This is done with a Gigli saw before the division of the tibia since greater stability of the extremity is helpful during this procedure The periosteum is treated in the usual manner

The tibia is then divided with a saw The surrounding stump must be protected with gauze strips or a pad during this step so that small bone particles will not be left in the stump The sharp anterior margin of the tibia is removed with the saw and then beveled with a file so that there will be no sharp point of pressure beneath the anterior layers of the stump During all the above procedures, retraction of the muscles when necessary should be quite gentle and maintained for as short a period as is possible

Arteries and nerves are treated as described above The muscles and fascia are then carefully approximated in layers over the end of the stump and the skin closed with interrupted silk

It is extremely important that there be no tension at the end of the stump or necrosis will result If there is tension, it is advisable to remove sutures and excise sufficiently more tibia to allow a satisfactory closure

An ample dry dressing is applied to the stump, using large gauze squares of several thicknesses, and an outside pad, bandage and adhesive applied as described under lower leg guillotine amputation It is also necessary from the point of view of comfort to the patient and immobilization of the stump to apply a long posterior splint

The postoperative care of the stump will be considered later under postoperative care of major amputations in general

The closed amputation through the lower leg advocated by Dr Beverly C Smith[7] of New York is best described by means of the series of illustrations shown in Figures 480-489

Gritti-Stokes Amputation Advantages The Gritti Stokes amputation is ideal in the patient who must be very active on his artificial leg for hours at a time The length of the stump and its ability to stand direct end bearing makes it very suitable for such strenuous use It is true, however, that walking is more difficult and the gait more unnatural than if the patient has his own rather than an artificial knee joint

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Fig 482 After division, tibia is drawn forward and medially out of wound with a bone hook Peroneal group of muscles is retracted laterally, fibula is exposed *below* site of division of tibia It is more accessible there than above proximal tibial stump Fibula is divided with a strong bone-cutting forceps so placed (see insert) as not to extend behind fibula where it may divide peroneal vessels which lie medially and posteriorly to fibula

Fig 483 An incision is carried circularly around extremity at right angles to lower end of vertical incision through skin, subcutaneous tissue, and deep fascia so that neither of these structures is separated from one another Deep fascia is raised from muscle beneath for a distance of about 2 cm Some of its extensions between muscle bellies are divided This skin subcutaneous tissue and deep fascia flap is so made as not to interfere with circulation of skin from subcutaneous tissue This step may be performed before or after division of fibula and before removing it from its investing muscles (Figs. 480-483, Dr. Beverly C Smith)

Fig 484

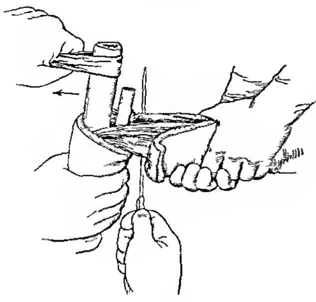
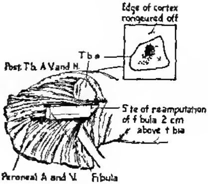


Fig 485



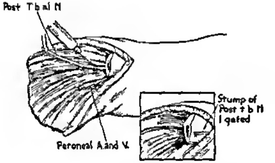


Fig 486

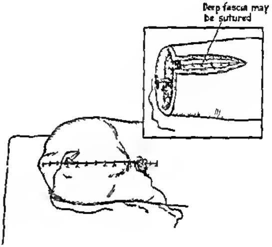


Fig 487

Fig 484 After dividing fibula, lower third of leg is depressed at a right angle to upper portion Lower divided fibula end is guided through the muscles with finger to prevent their injury Tibia has been previously separated from its investing muscles Those of fibula are now dissected from it with a curved scissors, keeping points directed against periosteum so as not to injure peroneal vessels, which lie posteromedially to fibula No periosteum should be left behind

The bones have now literally been removed from their investing muscles without dissection entering muscle bellies, practically a bloodless procedure which has preserved collateral circulation

An assistant standing at foot of table now makes distal traction on part to be amputated by means of one hand on heel and a towel around tibia and fibula This puts the muscles on a slight stretch Another assistant encircles upper part with his hands as a tourniquet A long amputation knife is then placed at angle of reflection of deep fascia of skin flap and the soft parts are divided transversely at a right angle with one firm sweep of the knife

Fig 485 Vessels are clamped with *small* hemostats and ligated individually, without surrounding muscle tissue with a ligature of either 0 or 000 plain catgut or fine silk Fibula is now dissected *from lateral side* from its investing muscles these retracted for adequate exposure and the bone again divided with a bone-cutting forceps 1 to 3 cm above end of tibia Division is made cleanly so as not to shatter bone, lower segment with its periosteum is peeled distally

(Continued on next page)

Nevertheless, it is also true that to many patients the advantage of a knee joint (as in the lower leg amputation) is of less importance than is the ability of the stump to take constant punishment without getting into difficulty A patient fortunate enough to have an ambulatory or a standing job in spite of an amputation cannot afford the loss of either the time or the money resulting from recurrent or persistent lesions common in an overworked lower leg stump In such cases the Gritti Stokes amputation is the logical answer to the problem

Unfortunately this amputation has a rather limited use in the diabetic and comparatively few patients are able to meet all the requirements necessary for its selection Most of these patients are in the upper age brackets and very few of them have been actively working Of those who have, only a small percentage are able to continue with the additional handicap of an amputation In other words, in the great majority of diabetics requiring amputation one is not stimulated to perform an amputation whose chief advantage will be wasted The low thigh amputation is best suited to most of these patients and will be discussed below

DISADVANTAGES In addition, the Gritti Stokes has certain definite immediate disadvantages as compared with the low thigh amputation, which contraindicate it except in very carefully selected cases The disadvantages are (1) A tendency to necrosis at the skin edges along the line of incision (2) increased incidence of postoperative infection, and (3) prolonged drainage of serum or synovial fluid

These complications, although usually minor, are important because they prolong the postoperative stay in the hospital They occur because of the normally limited blood supply to the tendinous structures in this region and because the amputation itself is necessarily associated with considerable ma

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out of stump from peroneal muscles Prominent sharp edge of crest of tibia is rongeured off but not so deeply as to enter medullary cavity which predisposes to bleeding and local hematoma formation, and may necessitate a drain to that region

FIG 486 Posterior tibial nerve is freed from vessels, pulled down, injected through a No 22 to 26 gauge needle with 1 cc of 1 per cent novocaine followed by 1 cc of absolute alcohol ligated with fine plain catgut or silk, divided with a knife, and allowed to retract upward behind tibia Artery in this nerve often attains considerable size as part of collateral circulation, and as nerve retracts, if untied, it may cause bleeding which if vigorously sought for may damage the existing collateral

Hemostasis is completed with *small* forceps and ligatures Wound is washed with at least three pitchers of saline brought immediately from sterilizers Hemostasis is again reviewed and wound is ready for closure after placing fresh towels about and under the part

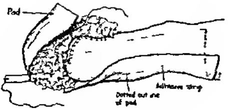
A solution of sulfanilamide or sulfathiazole may be used instead of saline, or up to 8 Gm of sulfanilamide or sulfathiazole powder may be sprinkled throughout the wound after using saline for cleansing purposes [See comments on chemotherapy, Chapter 22 —Ed]

FIG 487 The deep fascia may or may not be closed with fine interrupted (No 0 to 000 plain catgut or fine silk) sutures on a fine curved needle, depending upon texture of deep fascia and presence of tension If any tension is created by closing it, it is not closed In this case only the skin is closed with exactly placed fine silk sutures on fine cutting-edge needles

Exact skin approximation is essential The skin is *not* picked up with forceps but is held in gauze A drain of rubber dam, small Penrose tubing or a small soft beveled rubber tube may or may not be left in the dead space below either tibia or fibula and be brought out of end of wound or anteriorly just beyond tibia

A small safety pin is inserted through side of end of drain and a heavy piece of silk tied to safety pin is led out through dressing so that drain can be removed without disturbing dressing

When drain is removed on first to third day, its end is cultured aerobically and anaerobically The author prefers to drain these wounds He has closed some without drainage, he has not seen drainage do harm if placed and removed as described above (Figs 484-489, Dr Beverly C Smith.)



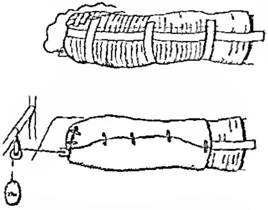


FIG 488 (*Top*) The dressing is extremely important—it immobilizes the part A strip of moleskin adhesive wide enough to encompass two-thirds of the diameter of thigh and leg and long enough to extend from lower third of thigh to just beyond end of stump is placed on skin of *thigh*, but between it and posterior skin of *leg* is a pad with a layer of gauze and petrolatum gauze over this (The latter keeps dressing from getting stiff against skin) This pad is long enough to cover end of stump, which has first been covered copiously by fluffed gauze Moleskin adhesive, pad, and fluffed gauze are held snugly by at least two large soft rolls which extend to midthigh and across end of stump

FIG 489 (*Center* and *Bottom*) A longitudinal strip of 2 inch adhesive holds this dressing in place on each side of leg and thigh, and similar sized circular strips pass three quarters around dressing A towel is in turn held snugly placed over this dressing and held with safety pins A two-pound weight is attached to end of moleskin adhesive strip with a ⅛- to ¼ inch cotton rope passing through a single pulley tied to foot of bed No pillow is allowed under stump—it rests on mattress

nipulation and handling of tissues This encourages necrosis and secondary infection which complicate and prolong the postoperative recovery

INDICATIONS The surgical requirements for a Gritti Stokes amputation are two·

A PALPABLE POPLITEAL ARTERY PULSATION The amputation is inadvisable in the diabetic group if the artery is occluded, even though the collateral circulation may be excellent

NO INFECTION ABOVE LOWER THIRD OF LEG (i e, no lymphangitis, cellulitis, or phlebitis, and no septicemia)

If the above requirements are met, the amputation is indicated in the following types of patient (1) One who is in better than average general condition and with every expectation of returning to an active life, and (2) one who is required to be on his artificial leg much of the day, either standing or walking

TECHNIC The proper placing of the skin incision is important and depends upon the accurate use of definite landmarks The incision which outlines the anterior flap is made as follows (Fig 490) The external and internal condyles of the femur are identified and grasped with the thumb and middle finger of the left hand A downward curved incision through the skin, fascia, and patellar tendon is then made between these two landmarks with the lowest point of the curve lying half an inch below the lower margin of the patella The incision outlining the posterior flap is then made through the skin and fascia and connects the lateral

the hook embedded in the divided patellar tendon. The fat and periosteum around the circumference of the patella are divided by the knife at the desired level for sawing. and clamped before division All lateral and medial structures are also divided. With the leg well elevated identification of nerves and vessels is simplified since the muscles

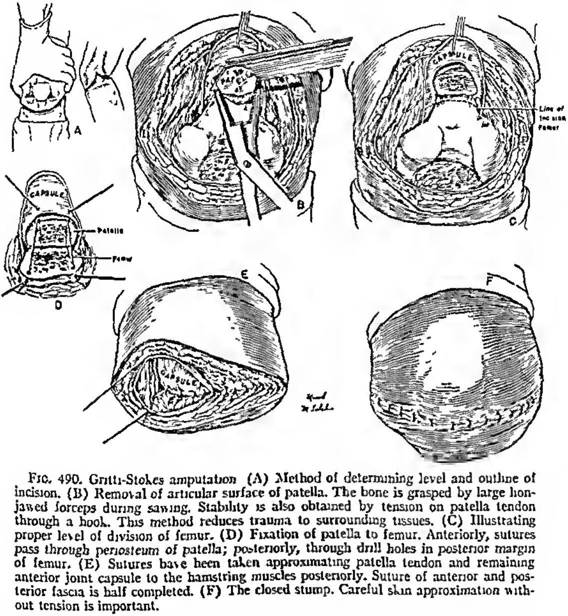


FIG. 490. Gritti-Stokes amputation (A) Method of determining level and outline of incision. (B) Removal of articular surface of patella. The bone is grasped by large lion-jawed forceps during sawing. Stability is also obtained by tension on patella tendon through a hook. This method reduces trauma to surrounding tissues. (C) Illustrating proper level of division of femur. (D) Fixation of patella to femur. Anteriorly, sutures pass through periosteum of patella; posteriorly, through drill holes in posterior margin of femur. (E) Sutures have been taken approximating patella tendon and remaining anterior joint capsule to the hamstring muscles posteriorly. Suture of anterior and posterior fascia is half completed. (F) The closed stump. Careful skin approximation without tension is important.

The patella is then grasped firmly at its circumference by large lion-jawed forceps to prevent slipping, and the articular surface is removed with the saw. The posterior incision is then carried through the muscles to the posterior surface of the femur, the nerves and main vessels being identified retract upward out of the way as they are divided.

The common peroneal and posterior tibial nerves and the popliteal vessels are the only structures that must be identified. The common peroneal nerve is quite superficial and lies beneath the fascia in relation to the

medial border of the long head of the biceps femoris The posterior tibial nerve lies superficial to but in close relationship to the popliteal vessels which are near to the posterior surface of the femur

Nerves and arteries are treated as described above

Remaining tissue in relationship to the circumference of the femur, including the periosteum is then circularly incised at the proper level The determination of this level is important, and is found by marking the point on the femur at which the superior margin of the cut surface of the patella rests without tension The femur is divided with the saw at this point There is no preliminary removal of periosteum since its presence is necessary for satisfactory union of the femur and patella

The patella is then fixed to the femur Two drill holes are made through the posterior margin of the femur The patella is brought down over the end of the bone, care being taken that no soft parts become interposed between the two Two doubled No 1 chromic catgut sutures are then taken through the tissues and the periosteum at the lower margin of the patella, each one being passed through the corresponding drill hole in the femur and firmly tied

The hamstring muscles are sutured to the cut patellar tendon with No 00 chromic catgut This helps to fix the patella more firmly to the femur and in addition obliterates the dead space controls oozing from the muscles and helps to balance the stump The fascia and skin anteriorly and posteriorly are approximated in the usual manner A simple sterile dry dressing is applied to the stump in the manner already described No posterior splint is necessary

Thigh Amputation The thigh (supracondylar) amputation is the procedure of choice in a large percentage of diabetics with serious lesions of the lower extremities As has been pointed out above, many of the major amputations occur in elderly patients who because of their age and diabetes have, in addition to foot lesions, other conditions which are of equal importance in the decision as to the type of amputation indicated General arteriosclerosis with serious cardiac, cerebral, and renal manifestations is common, together with varying degrees of involvement of the peripheral vascular system including the arteries of both lower extremities Other pathologic conditions, such as cataract or retinitis, occur frequently and are factors to be considered in determining the appropriate amputation In short, we are often faced with the problem of the elderly diabetic patient with many real or potential infirmities, whose general condition is hazardous and for whom we must do the safest and surest procedure Thigh amputation meets all the requirements because it is technically simple and is accompanied by fewer postoperative complications than any other amputation

In these cases it is obvious that the question of use of an artificial leg is of secondary importance since these patients have for the most part outlived the period of economic usefulness On the other hand, a thigh amputation does not necessarily mean a wheel chair existence We feel that, regardless of age, any patient whose ambition and general condition are such that an artificial leg is possible should be encouraged and taught to use one The mid or high thigh amputations of the past were too short to be usable except by young and active individuals The low thigh amputation described below, however, has proved useful in the type of patient we are interested in, since it is essentially supracondylar in type and has given excellent ambulatory results

As in other amputations, the level of infection is an important preoperative consideration On the other hand, adequacy of the arterial circulation is rarely a problem in the thigh amputation even when done as low as is possible The collateral circulation is rich enough even with occlusion of the femoral artery to give satisfactory healing in the great majority of cases If there is

any doubt as to the circulation, a warm skin to the knee without any abnormal color changes is sufficient indication that the cir culation is adequate for amputation at a low level

betic with hopeless gangrene or infection of a lower extremity

INDICATIONS 1 Circulation inadequate to make lower amputation possible (i e ab sent popliteal artery pulsation)

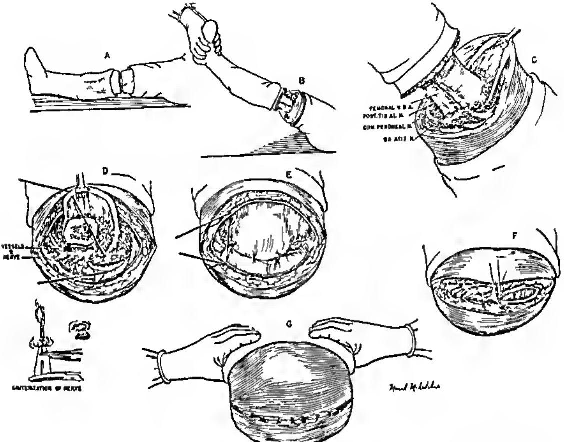


FIG 491 Thigh amputation (A) Level of circular incision It is just above superior margin of patella at supracondylar level of femur (B) Skin, fat, and fascia are divided cleanly in same plane (C) Muscles retract upward after division making retraction unnecessary to expose main vessels and nerves Note quadriceps tendon and upper limits of capsule and knee joint anteriorly (D) Main vessels have been tied and nerve crushed tied and cauterized (see inset) Note first suture passed between medial portion of quadriceps tendon and lateral group of hamstring muscles This prevents femur from taking a lateral position and tends to balance stump (E) Remaining sutures have been taken (as in D), and first suture approximating anterior and posterior fascia is in place (F) Fascial sutures are almost complete (G) Stump is entirely closed Skin sutures are not too constricting nor too close together

The indications for thigh amputation as listed below are largely self-explanatory and need not be discussed further Emphasis should be placed again upon the value of this amputation as the safest and surest means of treating the elderly, poor risk dia

2 Infection too extensive or at too high a level to permit a lower closed amputation

3 When the quickest and safest closed amputation is desirable and there is no high acute infection

4 Inability to use an artificial leg be-

cause of any of the following General poor condition, inadequate circulation in the other extremity, advanced age, permanently poor or failing eyesight, excessive overweight, mental instability, or previous loss of the other extremity, when the use of two artificial legs is impossible

5 Secondary to a lower leg guillotine amputation when the popliteal artery pulsation is absent or when any of the above indications are present

6 Gangrene or persistent painful ulceration of a lower leg amputation stump in the absence of a popliteal pulsation

TECHNIC A circular incision is used (Fig 491) The amputation is essentially a supracondylar one, the incision being made around the thigh at the superior margin of the patella (with the knee in full extension) The skin and fascia are divided in the same plane Anteriorly the incision is carried through the quadriceps tendon into the upper part of the capsule of the knee joint It is well to bevel the incision slightly so that the skin and muscles are longer medially than laterally This compensates for the increased power of the medial group of muscles which in the sutured stump exert a greater pull on the medial side of the stump than do the muscles on the lateral side Beveling therefore produces a more equally balanced symmetrical stump The large amputation knife which has been used for the skin incision should be changed or sponged off with alcohol before continuing with the amputation

With the leg well elevated and the knee still extended the posterior muscles are divided cleanly at the same level Small blood vessels are controlled by hemostats as they are cut As has been pointed out above, as little sponging as is possible should be done throughout the amputation, and every care should be taken to avoid handling of tissue within the stump It is especially important that no gauze, instruments, or suture material be allowed to come in contact with the skin

The nerves, i e, the common peroneal and posterior tibial, are easily identified as they are encountered during division of the muscles, and are clamped and cut

The popliteal vessels lie deep to the nerves and are in relation to the posterior aspect of the femur above the condyles These are identified, freed up, clamped proximally and distally, and then divided

All remaining muscles and tissue are divided down to the femur Following the usual treatment of the periosteum the bone is divided at the proper level, this point being approximately a distance from the skin incision equal to half the diameter of the thigh at the level of amputation During this maneuver the soft parts of the stump are protected and held back with a special amputation drape or a sterile towel placed closely around the bone

Each vessel should be tied cleanly and as little extra tissue included in the tie as possible In some cases with marked calcification it is well to crush the artery first or it may be difficult to occlude it completely with the tie Occasionally the bifurcation of the sciatic nerve is so near that time will be saved by treating it as above rather than treating each of its branches individually

The stump is now ready for suture This is done in two layers, using interrupted sutures The first and deeper layer is formed by suturing the posterior muscles to the cut end of the quadriceps tendon This balances the stump, controls bleeding from the ends of the muscles, and obliterates dead space at the end of the femur The second layer is sutured over this and is formed by approximating the anterior and posterior fascia The skin is then closed with interrupted No 8 silk Skin stitches should be fairly loose and not placed too closely together This avoids necrosis of the skin edges permits the escape of small amou blood which might otherwise accumul the stump and result in objectionable tomata.

A large dry dressing is applied in the usual manner as described above No posterior splint is necessary

A somewhat different method of performing a low thigh amputation has been worked out by Callander[5] and is described as follows*

The diagrams illustrate the stages of this amputation in the lower left thigh The patient is placed in the dorsal decubitus position, the knee of the diseased extremity is flexed slightly, and the leg is elevated a little above the horizontal on one or two sandbags No tourniquet is applied The surgeon stands on the side opposite the affected extremity and faces the medial aspect of the thigh and knee to be operated on He maintains this position throughout the operation because the essential steps are directed through a medial approach to the popliteal space From this position the operative work on the lateral part of the low thigh and knee are accomplished readily by rotating the knee medially

The skin incisions [Figs 492 and 493] outlining the slightly unequal anterior and posterior flaps are at the same level as the incisions that sever all the deeper soft parts The incision on the medial aspect of the thigh begins at a point three fingerbreadths proximal to the most prominent part of the medial femoral condyle [Fig 492] and runs horizontally distally in the palpable groove between the vastus medialis and the sartorius muscles With the knee in partial flexion this groove can be defined readily After the incision has been deepened to the enveloping or deep fascia of the thigh, the adductor tubercle of the medial femoral condyle and the tendon of the adductor magnus muscle, which inserts on it, can be palpated The skin incision continues distally over the medial epicondyle, sweeps forward, and crosses the anterior surface of the tibia at the anterior tibial tuberosity, the point of insertion of the quadriceps extensor tendon

The thigh then is rotated medially (i e, toward the surgeon) The skin incision on the lateral aspect of the leg, as outlined in Fig 493, begins at a point three fingerbreadths proximal to the lateral femoral condyle in the palpable groove between the tendon of the tensor fasciae latae (iliotibial tract) and the biceps femoris muscles The incision must be made very close to the tensor fasciae latae tendon in order to avoid the muscular fibers of the biceps Continuing distally over the lateral epicondyle the incision extends forward to meet the medial incision at the anterior tibial tuberosity, thus outlining the anterior flap of the amputation

Corresponding incisions from each femoral epicondyle are carried obliquely posteriorly and inferiorly until they meet on the calf of the leg at a point a little inferior to the level of the anterior tibial tuberosity This incision for the posterior flap is deepened to the fascia on the gastrocnemius muscle Thus are outlined two long amputation flaps, the posterior a little longer than the anterior Each flap partakes not only of the soft parts of the lower thigh but of a considerable portion of the soft tissue of the leg

Attention again is directed to the medial aspect of the thigh and knee [Fig 494] The horizontal portion of the medial incision common to the two flaps, i e, that portion lying between the vastus medialis and the sartorius muscles, is deepened through the deep fascia of the thigh Division of this powerful fascial layer, which is the only strong structure in the medial wall of the popliteal fossa at this level, affords ingress to the popliteal space The left forefinger, now inserted shallowly into the popliteal space [inset in Fig 494], frees the medial hamstring tendons to their tibial insertions by blunt dissection At this juncture these tendons are divided in the order named sartorius, gracilis, semimembranosus, and semitendinosus During this dissection no fleshy portion of any of the medial hamstring muscles nor any part of the vastus medialis muscle need be exposed, much less severed The severed hamstring tendons retract at once into the aponeurotic and areolar tissue of the posterior flap and are not dealt with again Further exposure is gained by severing the tendon of the adductor magnus muscle at its attachment to the adductor tubercle Free access to the vasculoneural contents of the popliteal space thus is afforded Moderate flexion of the knee relaxes the popliteal vessels and nerves and favors their manipulation With a finger now inserted more deeply into the popliteal space and kept close to the posterior surface of the femur, the popliteal artery and vein are withdrawn easily to a level flush with, or even outside, the skin incision [Fig 495] Here they are clamped, ligated, and divided as near the superior apex of the popliteal space as is

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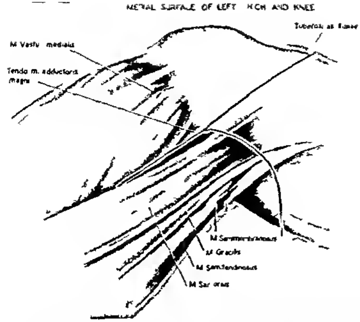

FIG 492 Medial surface of left thigh and knee skin incisions on medial side of low thigh and knee marking long anterior and posterior flaps Attention is directed to amuscular and avascular interspace between vastus medialis and sartorius muscles Note that flaps for this low thigh amputation are derived from soft parts of leg

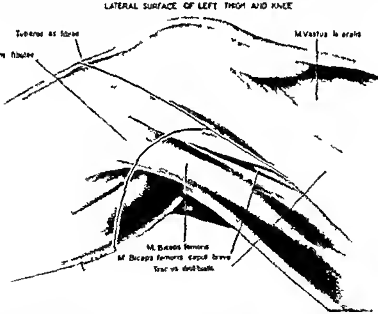

FIG 493 Lateral surface of left thigh and knee skin incisions on lateral side of low thigh and knee marking long anterior and posterior flaps Attention is directed to amuscular and avascular interspace between tendon of tensor fasciae latae (iliotibial tract) and biceps muscles Biceps muscle is composed of fleshy fibers almost down to its insertion on head of fibula

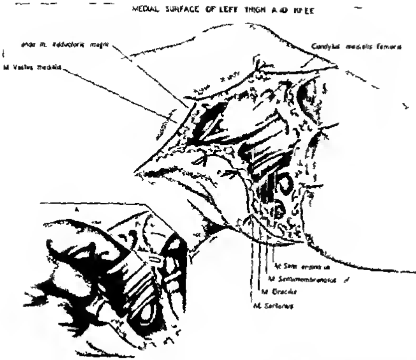

Fig 494 Medial surface of left thigh and knee deepening flap incisions through deep fascia on medial aspect of knee to expose medial hamstring muscles Inset shows bunching of medial hamstring tendons at their insertion on tibia, and method of their section

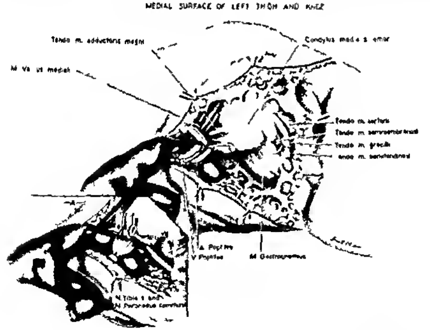

Fig 495 Medial surface of left thigh and knee further deepening of flap incisions on medial aspect of knee Vessels and nerves in popliteal space are sectioned Main drawing shows retraction of hamstring muscles after section at their tendinous insertions on tibia Contents of popliteal space now are widely accessible and vessels are ligated Inset demonstrates method of securing and dividing tibial and common peroneal nerves

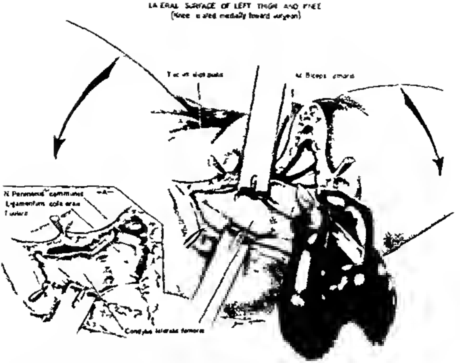

Fig 496 Lateral surface of left thigh and knee (knee rotated medially toward surgeon) deepening of flap incisions on lateral aspect of knee Left knee forcibly rotated medially Interval between iliotibial tract and biceps muscle is defined, and biceps is sectioned at its insertion on head of fibula Inset indicates structures deep to biceps tendon Common peroneal nerve already has been sectioned through medial approach (Fig 495)

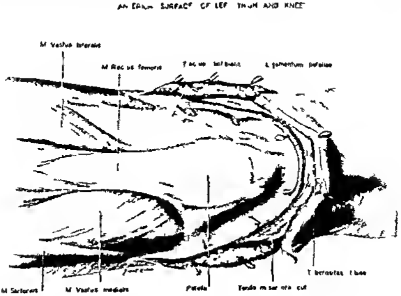

Fig 497 Anterior surface of left thigh and knee incision marking anterior flap is deepened through knee-joint capsule and infrapatellar tendon down to tibia

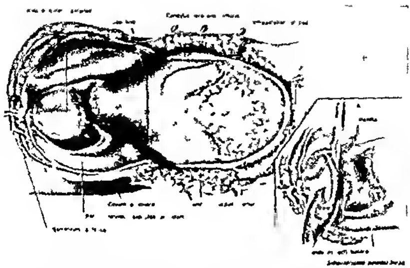

FIG 498 Anterior surface of left thigh and knee upward dissection of anterior flap and removal of patella from joint side The saw line in main drawing is well down into condylar flare Inset shows sharp dissection of patella from its fossa in quadriceps tendon, leaving rectus femoris tendon intact to act as a buffer for cut end of femur.

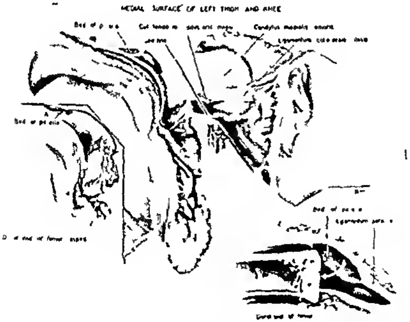

FIG 499 Medial surface of left thigh and knee section of femur after formation of long anterior and posterior flaps (Inset A) shows patella fossa ready to receive cut end of femur (Inset B) shows anterior flap loosely approximated to posterior flap As flaps unite and posterior flap retracts, patellar fossa lodges femur end

convenient The tibial (internal popliteal) and common peroneal nerves then are drawn readily into the wound as one trunk [inset, Fig 495] and are anesthetized, ligated, and divided Each of the components of the nerve bundle is injected with absolute alcohol to prevent neuroma formation, and the stump is allowed to retract into the proximal recess of the popliteal space

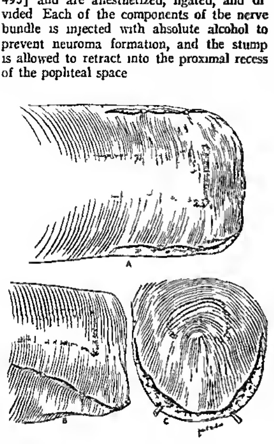

Fig 500 Transparency drawings to show location and size of condylar end of femur in redundant amputation stump (A) View of the stump from front, (B) stump seen from side, (C) stump viewed from end before clips have been placed Skin clips are the only means of approximating flaps at time of operation

The partly flexed knee now is rotated toward the operator [Fig 496], and the lateral longitudinal skin incision is deepened through the deep fascia of the thigh The incision is carried through the deep fascia as far as the insertion of the biceps muscle on the head of the fibula, where the biceps tendon then is severed At this stage of the operation the popliteal space may be opened widely from side to side since the essential structures have been divided Deepening of the incision marking the posterior flap down to the gastrocnemius aponeurosis, and clearing from it the areolo adipose debris, free the posterior flap It is advantageous to leave the fibro-areolar tissue of the popliteal space in contact with the femur as far down as the level of the adductor tubercle in order that there may be as little dead space as possible between the posterior flap and the femur

The knee then is extended [Fig 497] and the incision marking the distal portion of the anterior flap is deepened through the capsule of the knee joint down to the femoral condyles and to the tibia, thereby severing the quadriceps tendon at its insertion into the tibial tuberosity The anterior flap containing the patella is dissected upward off the infrapatellar fat pad and drawn upward on the thigh until the superior synovial recesses of the subquadriceps space are seen [Fig 498] The patella is dissected from its sesamoid position in the quadriceps tendon, care being taken to preserve the longitudinally disposed tendon of the rectus femoris muscle, which runs over it [inset, Fig 498] Preservation of this tendon adds materially to the end bearing capacity of the stump after the cut end of the femur is fitted into the socket from which the patella has been removed The synovia on the anterior flap and over the femur proximal to the condyles is not excised The femur now is sawed through the cancellous portion just proximal to the adductor tubercle [Fig 499] At this level the shaft of the femur has expanded to a size that approximately corresponds to the patellar socket in the quadriceps tendon The cut end of the femur is rounded with a rasp until no sharp surfaces and no fringes of periosteum remain

The two large flaps are inspected now for small bleeding points These can be ascertained best by sluicing the surfaces of both flaps with large quantities of warm salt solution This flushing has the additional advantage of washing away small soft tissue and bone debris Many small bleeding points may require ligation after this procedure Inspection of the body of the posterior flap shows no muscle fibers but only areolo adipose tissue and the cut ends of the hamstring tendons These tendons already are retracted into their aponeurotic beds and are scarcely visible The flaps now are allowed to fall together loosely [inset B, Fig 499]

The only coapting suturing during the operation is in the form of not more than four to six clips or sutures placed at such intervals as to keep the flaps in fair apposition [Fig 500]

When the skin edges are approximated, the aponeurotic edges also lie in contact, mere apposition is sufficient to produce firm union None of the tendons or aponeuroses of the anterior flap are sutured to the corresponding structures of the posterior flap In this way no structure is under any tension, and the trauma and consequent pressure necroses resulting from suture of these deeper structures therefore cannot occur The flaps appear exceedingly long and even extend an inch or more beyond the femur end immediately after they are fashioned To the surgeon accustomed to the routine type of low third femur amputation, the flaps will appear excessively redundant and clumsy, and he will fear that a bulbous stump end and large dead spaces will result He will wonder, too, when he notes how wobbly the femur lies between the flaps, how the femur end will gain contact with the patellar socket and fuse there During the early days of convalescence, the reason for leaving these flaps under no tension appears At the end of the second or third postoperative day and sometimes even within a few hours after the operation, the hamstring muscles, severed only at their distal attachment, contract to the degree that the skin suture line lies posteriorly placed at about the level of the stump end, and the femur is felt in the patellar fossa

[For further details in relation to amputations, see Chapter 19 —Ed]

Postoperative Management of Major Amputations The management of the diabetes has already been discussed in detail and need not be repeated here The bed care of the patient who has had a major amputation is extremely important and includes specific measures essential to a satisfactory convalescence These measures are designed to prevent the complications that are most likely to occur in the surgical diabetic and include the following

Morphia, Pantopon, or Dilaudid One of these may be given in small doses every three or four hours, if necessary, to control the pain

Balkan Frame The bed of every amputation case should be equipped with a frame by the time the patient has returned from the operating room This allows the patient to move himself in bed without exerting harmful pressure on the heel of the remaining foot, which may result in pressure necrosis The latter is an unfortunate and avoidable complication that must be guarded against The frame is also of great aid in the general nursing care since the patient can also use the suspended handles in helping to raise himself for the use of a bedpan, etc

Protection of Remaining Foot This may be accomplished by

1 a firm pillow placed under the calf to elevate the heel from the bed

2 a wire frame or cradle placed at the foot of the bed to prevent pressure on the toes by the bedclothes

3 a heavy woolen sock worn to protect the foot against trauma and to keep it warm

4 daily foot care, including bathing with warm soap and water, and the use of toilet lanolin to prevent excessive dryness of the skin Nails corns, and calluses are treated as the occasion arises

5 buerger exercises to stimulate circulation are indicated in the later stages of the convalescence

Measures to Prevent Furuncles and Areas of Pressure Necrosis of Back Diabetics are particularly susceptible to necrosis due to pressure over the sacrum (1) The patient is turned every two hours day and night and the back rubbed with alcohol and powdered (2) There should be no rubber sheet beneath the patient (i e , as a protection to the mattress) This, if used, is a factor in the production of lesions of the back by causing greater moisture of the skin

Bed Exercises Bed exercises including motions of the arms and of the remaining extremity should be employed in the later stages of the convalescence to stimulate metabolism and increase muscle strength

Postoperative Care of Amputation Stumps 1 General Care Upon return from the operating room the patient is kept

flat in bed for a period of four hours in accordance with the usual routine after spinal anesthesia The stump is placed flat on the bed and is steadied on either side by sand bags The practice of elevating the stump on a pillow is objectionable because flexion of the hip over a period of several days tends to produce a definite contracture This is difficult to overcome later and is a great handicap in the use of an artificial leg

When the patient is turned on his side, as he is every two hours the stump is supported by a soft pillow placed between the knees or thighs The sandbags may be eliminated after three to five days when motion of the stump has become less painful

The importance of morphine, etc., for the relief of severe pain during the first few days has been mentioned above

In all closed stumps—i e the lower leg Gritti Stokes and thigh amputations—the first dressing is done on the fourth or fifth day unless an elevated temperature or tenderness and edema above the dressing make earlier examination indicated One-half of the skin sutures may be removed at this time If there is any suggestion of secondary infection that part of the incision is opened by removal of stitches and separation of the skin edges A culture is taken of any exudate present Too vigorous palpation or active probing is objectionable at this time and may cause extension of a minor subcutaneous infection which would otherwise rapidly subside

If the stump is satisfactory, the incision is bathed with alcohol or painted with tincture of metaphen and a similar sterile dry dressing re applied The remaining sutures are removed on the tenth to twelfth day, depending upon the degree of healing which has occurred

The application of heat to stumps in which infection is suspected is rarely helpful In extensive subcutaneous or deep infection adequate early drainage is indicated and is accomplished by removal of all the stitches and by secondary incisions if necessary In conjunction with these measures packs or irrigations with suitable antiseptic solutions such as Dakin's solution or azochloramid in saline (1 3300) may be used If incisions are necessary they should be longitudinal and adequate enough to lay open the full extent of the infected area Inadequate incisions will not check the infection, which tends to progress upward indefinitely Stump infections in the diabetic characteristically extend up the fascia lata in the thigh and unless controlled will ultimately be fatal

The complication of stump infection as discussed above should not occur it indicates either an error in judgment in electing to do a closed amputation, or an operative contamination due to faulty technic

2 Stump Care in Relation to Specific Types of Amputation lower amputation The posterior splint is not removed for eight to ten days At that time the postoperative sensitivity to pressure and motion has disappeared and the incision is practically healed

At the first dressing one may find edema of the stump without any evidence of infection This, if allowed to persist, increases tension over the end of the tibia and may result in necrosis of the overlying skin In these cases carefully applied adhesive skin traction below the knee is helpful and should be maintained until the edema has subsided

The complication of gangrene of the stump due to thrombosis of the femoral or politeal artery in cases improperly selected for lower leg amputation has been discussed Secondary thigh amputation is indicated

The postoperative care of the lower leg amputation stump is otherwise as described above

lower leg guillotine amputation If the patient shows no evidence of acute infection and has a satisfactory chart, the ointment dressing applied at operation need not be changed for five to seven days However, if drainage is profuse, it may be neces-

sary to do the dressing earlier If the open end of the stump is clean, a similar dressing is re applied and changed thereafter as often as is necessary

In the cases in which gross infection de velops in the stump, Dakin's solution or azochloramid in saline should be started The most satisfactory method of application is through Dakin's tubes placed in the dress ing over the end of the stump Enough solution may then be instilled through the tubes (i e, 5 to 10 cc every two hours) to keep the dressing moist and effective If the azochloramid solution is used, instillation every six to eight hours is sufficient The patient s comfort during the dressings is greater if a fine meshed, closely woven ma terial (compress cloth) is used directly over the end of the stump rather than the usual coarse gauze which becomes adherent to the exposed tissues and whose removal is pain ful As has been mentioned above, this should also be used in the clean cases in which boric or codliver oil ointment is em ployed as the dressing of choice

In stumps with extension of infection along the fascia or muscles the same princi ples of drainage apply as have been dis cussed

The posterior splint is used up to the time of the secondary higher closed ampu tation It contributes greatly to the comfort of the patient and helps to maintain com plete stability of the dressing

We have discussed the importance of per forming secondary closed amputation in these cases The facts that a healed lower leg guillotine stump is unsatisfactory for use with a prosthesis and that secondary closed amputation shortens the hospital stay are logical reasons for this practice The secondary amputation is done only when the patient s general condition has sufficiently improved and when infection is under con trol, as evidenced by a normal temperature for a period of several days The optimum time for operation may vary from one to two weeks in the average case One of the important advantages of the guillotine am- putation, in addition to its value as a life saving measure, is that in the sicker patients one may wait indefinitely before doing the secondary closed amputation provided more time is necessary to accomplish the desired improvement The type of closed amputation done depends upon the require ments of the individual patient and may be either a Gritti Stokes or a low thigh Mor bidity and mortality is extremely low in the above when done secondary to a clean lower leg guillotine amputation

THIGH GUILLOTINE AMPUTATION The care of the stump is essentially the same as in the lower leg guillotine amputation These stumps, however, are difficult and serious problems because of the presence of exten sive high infection The mortality is high therefore, and prolonged hospital stay is the rule

Infection in the thigh is characterized by necrosis of the fascia and a gradual exten sion to higher levels which is difficult to check Success is possible only by early and completely adequate drainage of all infected areas Extensive longitudinal incisions, so as to give complete and dependent drainage together with the use of Dakin s or azo chloramid solution, offer the only means of saving the patient Chemotherapy, when in dicated by the type of organism cultured, and supportive measures including transfu sions for secondary anemia should be used here, of course, as in any serious infection in the diabetic

After the infection has subsided, closure is accomplished by adhesive traction and skin grafting The traction may be applied fairly early unless its use will interfere with necessary drainage of some part of the stump It is maintained until the muscles and fascia have been pulled down suffi ciently over the end of the femur to allow fixation and granulation to occur Skin grafts (pinpoint being the surest) may be applied later to hasten final healing

Secondary suture should not be done,

since it is rarely successful in the diabetic and usually results in a flare up of infection

GRITTI STOKES AND THIGH AMPUTATION The care of these stumps has been covered under the general care of stumps

Complications of Major Amputation. The complications following amputation fall into four groups (1) General infection secondary to that of the amputated extremity, (2) infection of the stump, (3) other stump complications, and (4) conditions secondary to general obliterative vascular disease or diabetes

1 GENERAL INFECTION Septicemia existing preoperatively and persisting after amputation is the most serious surgical complication and is an important cause of death Unfortunately it is often unavoidable, and will continue to be so as long as late cases of gangrene and infection present themselves for treatment In these cases the surgeon cannot be criticized if he has recognized the septicemia preoperatively and has performed a prompt guillotine amputation On the other hand, he should be held responsible for a postamputation septicemia in a case in which he has previously done an unsuccessful local procedure Treatment of the septicemia is too often of no avail, but should consist in general supportive measures adequate fluids transfusions for secondary anemia etc Chemotherapy if effective may save the life of the patient Metastatic abscesses, both superficial and deep, are common, especially if the organism is the staphylococcus These abscesses should be located and drained as promptly as possible

2 INFECTION OF AN AMPUTATION STUMP This may be a fatal complication unless recognized early and treated promptly This has been discussed in detail under the post operative care of stumps In these cases death may result from extensive prolonged sepsis or from an acute process terminating in a septicemia.

3 OTHER STUMP COMPLICATIONS SECONDARY HEMORRHAGE This should be extremely rare both in clean closed stumps and in those that are infected

Mention has been made of the desirability of markedly crushing calcified main vessels before tying to insure complete occlusion at the level of the tie This prevents bleeding from the lumen of the artery into the deeper layers of the stump A large usually pulsating hematoma is evidence of this The treatment consists in immediate return to the operating room where the skin, fascial and muscle sutures are removed and the vessels retied after removal of the clot. A tourniquet may be necessary The stump is then resutured It must not be drained

Secondary hemorrhage in massively infected stumps is uncommon even when the main vessels are bathed in pus Thrombosis occurs rapidly under these conditions in an artery which already has more or less arteriosclerotic degenerative change This is the best insurance against secondary hemorrhage

NECROSIS OF INCISION The skin margins may become necrotic in any stump that is secondarily infected It is most often seen, however, in the lower leg amputation where the circulatory margin of safety may be small It is also not uncommon to find a narrow zone of skin necrosis in relation to the edge of the posterior flap in the Gritti Stokes amputation There is no specific treatment in either case save that of infection if present Healing must be by second intention and is therefore considerably delayed

GANGRENE OF STUMP This rarely occurs except in cases improperly selected for lower leg amputation, and has been discussed above Gangrene of the stump is due to thrombosis of the popliteal or femoral artery and the treatment is re amputation at a higher level

Stump ulceration and pressure lesions also occur, largely in the lower leg amputations, and have been considered

Minor pressure lesions occur but rarely in the thigh or Gritti Stokes stumps, and

rapidly subside with rest or re adjustment of the artificial limb

DEEP PHLEBITIS This is an unusual com plication in the diabetic, but explains the occasional thigh or Gritti Stokes stump which shows edema without any evidence of infection in the stump Possibly some of these cases are on a lymphedema basis rather than due to a phlebitis In any case they subside gradually with simple eleva tion We have seen only one pulmonary embolus in these cases

PAINFUL STUMPS Except for the phantom foot pain which is the usual early complaint of most patients following amputation pain ful stumps are not a problem in the diabetic The cauterization of the nerves together with the other technical points discussed above contribute to the satisfactory results It is probable however, that a comforta ble stump depends upon many factors The most important of these are An operative technic which insures clean, sharp division of all tissues, including nerves healing without deep infection and a flexible non adherent stump

4 CONDITIONS SECONDARY TO GENERAL OBLITERATIVE VASCULAR DISEASE OR DIABETES These complications as repeatedly pointed out above, are necessarily common in the elderly diabetic group and are re sponsible for much of the mortality It is unnecessary to do more than enumerate them

CARDIAC DISEASE Coronary thrombosis is common

CARDIORENAL DISEASE Chronic urinary in fection may also occur and is an important additional factor

CEREBRAL THROMBOSIS

PULMONARY DISEASE Terminal broncho pneumonia is frequent Pulmonary embolus may occur

DIABETES Hyperglycemia hypoglycemia, and acidosis are important and need not be discussed here

Mobilization of Patient. The importance of the care of the remaining extremity and the measures used to protect it during the postoperative bed period have been con sidered During this time one must think of the foot not only in respect to its hygiene and the prevention of pressure necrosis but also from the point of view of its future usefulness This is particularly important in the patient who is to use an artificial limb since his ability to be active depends upon a serviceable extremity It is all too easy in a patient who is convalescing following an amputation to focus one s attention on the immediate problem of the amputation stump and to forget the good extremity Inactivity of the latter may further impair an already reduced circulatory efficiency to such an extent as to make it incapable of standing the additional burden which ac companies the use of a prosthesis There fore, an essential part of the mobilization of all postoperative patients who have poor circulation in the remaining extremity, or who have had a prolonged period in bed is stimulation of the peripheral circulation by the means already considered i e Buerger exercises and bed exercises

Elderly patients should not be kept in bed any longer than is necessary following amputation The length of time will, of course vary depending upon their general condition and the amputation stump Pa tients who were poor operative risks due to long standing chronic infection of an ex tremity and who may have associated com plications, such as uncontrolled diabetes with cardiac or renal difficulties, will of necessity require a more or less prolonged period of postoperative bed care Such cases should be mobilized as soon as there is suffi cient improvement to permit gradually in creased activity

Obviously the process of getting the pa tient up should not be sudden, but should be started cautiously by allowing him first to sit on the edge of the bed This is fol lowed by short periods in a chair as soon as his steadiness and strength are adequate Wheel chairs are contraindicated at this

stage because of their instability and the tendency of some patients to overexert themselves if given the opportunity

The average patient who does well following amputation and has a clean closed amputation stump can be sitting in a wheel chair on the eighth to tenth day after operation Occasionally it is advantageous in quite elderly but active patients to get them up earlier in order to reduce the possibility of complications resulting from bed inactivity such as pulmonary edema or pneumonia

Any patient regardless of age whose condition is reasonably good should be given the opportunity to use an artificial limb Reasonably good condition presuppo es the absence of severe cardiac disease, marked weakness, blindness, or any other condition which contraindicates walking A definite routine should be followed in this as in all other stages of mobilization of the patient It is our custom to measure the patient for crutches as soon as he begins to sit up in a chair When he has gained sufficient strength he is given a trial at standing with the crutches and, if he does well, he is helped to use them in walking By this time it is possible to determine accurately whether or not his strength and balance are good enough to warrant a temporary artificial limb If so he is measured by the limb maker and a temporary peg leg (see below) obtained This is used with crutches for a period of several days before discharge from the hospital so that he may become familiar with its use and be able to carry on with it at home

The instruction in the use of the temporary peg leg while the patient is still in the hospital is very important if he is ever to become really ambulatory It is often true that if he is sent home with instructions to obtain a prosthesis later, he either never gets one at all or, if he does, he becomes so discouraged with its use that it is discarded In other words a proper start in the hospital with expert instruction and help often makes the difference between success and failure in the use of an artificial limb

Further detail as to artificial limbs is given below

Artificial Limbs TEMPORARY LIMBS We have discussed the method of mobilizing the patient following amputation, including his instruction in the use of a temporary limb The most satisfactory type of the latter is the temporary peg leg This is the most valuable appliance we have for teaching these patients how to walk Elderly individuals in particular who would be unable to handle a permanent limb with its artificial knee joint and foot do surprisingly well on this simple appliance Some of them in fact are satisfied to use it permanently rather than to pay for the much more expensive permanent artificial limb

Regardless of age or the type of stump it is necessary that the patient be fitted to the temporary appliance as early as his condition and the stump permit This does away with the inactivity of waiting several months until the stump is ready for a permanent limb Such a delay is objectionable in that it is inevitably associated with loss of strength and ambition It is additionally harmful in that much sitting over a prolonged period results in a definite flexion deformity of the hip which makes the use of a permanent artificial limb much more difficult Therefore, since most of these patients are beyond middle age and adjust themselves poorly, early use of the temporary peg leg is the most important factor in the successful later use of a permanent artificial limb

The temporary peg leg is constructed so that most of the weight is taken on the padded upper margin of the bucket The bucket is also adjustable in size, which allows it to be tightened up with laces as the stump decreases in diameter This not only insures a proper fit at all times, but is distinctly beneficial in helping to mold the stump in preparation for a permanent limb

Some of the younger or very active patients may wish to have a temporary limb which is not quite so unsightly There is no objection to one with the same type of laced bucket but which is equipped with a foot and in addition has the practicable advantage of a joint at the knee level This does not act as a knee joint in walking, but can be unlocked by hand when the patient sits, so that the limb bends at right angles and does not extend straight out

The temporary peg leg as described is used in both the Gritti Stokes and low thigh amputations In the Gritti Stokes the weight is first taken at the top of the bucket as in the low thigh Later as the end of the stump becomes less sensitive end bearing is gradually obtained by building up felt pads at the bottom of the bucket

The same procedure may be followed in the low thigh amputations, many of which are able to bear some weight on the end of the stump

The average patient with a low thigh or Gritti Stokes stump can start using the temporary limb at the beginning of the third week

The same type of temporary peg leg is used in the lower peg amputation, the weight being taken below the knee on the top part of a small laced bucket This stump however cannot be used as early as either the Gritti Stokes or the thigh since complete healing is more prolonged The average case can start using the temporary limb in the fourth week if the stump is satisfactory

Permanent Limbs Many of the elderly diabetics, as pointed out above, are able to use a temporary peg leg fairly well but are not adept enough to handle the much more complicated and difficult permanent artificial limb Most of those, however, who do well with the peg leg look forward to the time when they can walk with the more natural appearing permanent leg Those who do poorly with peg leg should not be permitted to waste money on a permanent appliance which one can definitely predict they will be unable to use

A permanent artificial limb is of course desirable when practicable in any given case but should not be obtained too early A period of three to six months on the temporary limb is desirable in order that the stump may have had time to reach its final size This necessary delay will avoid repeated adjustment of the permanent limb during a period when the stump is still decreasing in size [For further details as to prostheses, see Chapter 19 —Ed]

AMPUTATION IN ARTERIOSCLEROSIS NONDIABETIC

The types of lesion and the indications for amputation in the nondiabetic arteriosclerotic differ little if any from those already discussed in relation to the diabetic The management of these cases is therefore essentially the same except for simplification of the medical problem in the absence of diabetes

These patients typically present themselves for treatment with painful extremities which may show no open lesions or may have all degrees of gangrene varying from small pinpoint areas of necrosis to complete gangrene of one or more toes Infection is common and is almost as serious a problem here as in the diabetic Therefore it is essential that the surgeon avoid doing minor amputations except in the presence of good collateral circulation An ill advised toe amputation in a pulseless foot may precipitate a rapidly ascending fatal infection Also, extensive minor amputations including one or more metatarsophalangeal joints are safe and successful only in the most carefully selected cases

The indications for minor and major amputation will be enumerated The preoperative care, anesthetic, technic, and postoperative care are exactly the same as discussed above

Indications for Minor Amputation Amputation of a Toe. 1 Osteomyelitis of

a phalanx in the presence of a good dorsalis pedis pulsation There must be no acute lymphangitis

2 Osteomyelitis of a phalanx without gangrene or lymphangitis in a pulseless foot which has good collateral circulation This presupposes a warm, well nourished foot without striking color changes on elevation or dependency

3 Gangrene limited to the distal portion of a toe in a pulseless foot with good collateral circulation (as above) and no acute lymphangitis In addition, a palpable popliteal artery pulsation is required together with freedom from pain after a two week period of conservative treatment in the hospital

Indications for Major Amputation. 1 A painful extremity with or without gangrene in which pain persists after three weeks of conservative hospital treatment

2 Gangrene of one or more toes in a pulseless foot with acute lymphangitis or extensive deep infection which cannot be controlled by conservative local measures i e hot moist compresses

3 Gangrene of one or more toes when there are no peripheral pulsations below the femoral artery and the collateral circulation is poor

Level of Amputation. Factors determining the level of amputation are essentially the same as in the diabetic and need not be rediscussed We will emphasize the fact that the low thigh amputation as described above is also the simplest and safest amputation in this group and the operation of choice in the great majority of elderly arteriosclerotics with senile gangrene Also, the guillotine amputation is a life saving measure and is indicated in all cases of septicemia or high acute infection

AMPUTATION IN THROMBO ANGIITIS OBLITERANS

In the differential diagnosis discussed above we have pointed out the general characteristics of thrombo-angiitis obliterans in respect to its age incidence, its chronic progressive course, and its tendency to involve all four extremities

The disease has two other important characteristics which are in contrast to peripheral arteriosclerosis (diabetic and non diabetic) and which play an extremely important part in its management These are (1) A greater tendency to develop collateral circulation, and (2) a much greater resistance to infection The former permits more extensive successful minor amputations than is possible in the arteriosclerotic with a comparable degree of main vessel obliteration The latter reduces the incidence of rapidly ascending acute infection or septicemia which is so characteristically high in the arteriosclerotic group Therefore, in thrombo-angiitis obliterans the indications for minor amputation are broader and many more extremities can be saved, while major amputation, although occasionally necessary, need rarely be done as a life saving procedure.

The age incidence of the disease is another factor which encourages conservative measures and justifies prolonged hospital treatment Amputation of toes and drainage of the deeper structures of the foot should therefore be attempted before considering major amputation, except, of course, in the occasional case with hopelessly extensive gangrene or infection

It is not within the scope of this article to discuss details of treatment other than those related to amputation, but mention must be made of two operative procedures that are of great value in the management of thrombo-angiitis obliterans

Peripheral nerve block as described by Smithwick and White[6] has saved many extremities by relieving pain and permitting adequate treatment of local lesions It is also of benefit in that vasodilatation is produced in the foot over the distribution of the nerve that has been blocked

Lumbar ganglionectomy is helpful and is indicated in cases that have an associated

vasomotor spasm In suitable cases it is excellent prophylaxis against future gangrene and possible loss of the extremity

The anesthesia, technic, and postoperative care of all amputations are as described above

Indications for Minor Amputation It is unnecessary to enumerate specific indications in that we have pointed out above that, in contrast to the arteriosclerotic group amputation of one or more toes with or without more radical local procedures in the foot is comparatively safe and often successful in thrombo angiitis obliterans

Indications for Major Amputation These are (1) Acute rapidly ascending infection, (2) extensive progressive gangrene in spite of the usual conservative measures, and (3) gangrene or infection so extensive that a useful foot cannot be obtained even if healing occurs

Level of Amputation The Gritti Stokes is the amputation of choice in thrombo-angiitis obliterans and can be done safely even in the absence of a popliteal artery pulsation.

We believe that the lower leg amputation is rarely if ever indicated Arterial deficiency of the stump is a probability because of the progressive nature of the disease

It is rarely necessary to do a thigh amputation in these cases

The lower leg guillotine amputation may be indicated in the occasional rare case with high acute infection A secondary, closed, higher amputation, preferably a Gritti-Stokes, is done after the acute infection has subsided and when the patient's general condition permits

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Cineplastic Amputations

HENRY H KESSLER, M D

Because of the unsatisfactory experience with the ordinary mechanical arm after upper-extremity amputations, attention has been directed toward the development of a substitute arm in which the control can be achieved by natural muscular action This development is marked by the names of Vanghetti, Ceci, Pellegrini, Putti, Sauerbruch, and Bosch Arana

Many methods have been devised for utilizing individual muscles or muscle groups to activate an artificial limb The chief forms of these motors were the club motor, the loop motor, the tendon tunnel motor, and the pseudarthrosis motor of Putti These forms of kineplastic surgery are of historical interest only since they are rarely used today The muscle tunnel motor used by Sauerbruch and Bosch Arana has given such satisfactory results as to warrant universal adoption

In the kineplastic amputation the muscles remaining in the amputated stump are utilized to activate the prosthesis By means of pegs passed through canals created in these muscles and attached to levers operating the artificial hand mechanism, the physiologic action of the stump muscles in the upper arm, and of the flexors and extensors of the lower arm, control the grasp and release of the fingers of the artificial hand Thus, the stump retains its real task of guiding the hand without the addition of other problems, such as leverage, as is the case in the ordinary mechanical arm Though the fingers of the artificial h… have no feeling, natural control is, neverth… less, exerted by the muscles in the act … grasping, thereby permitting a close a… proximation to natural hand function

OPERATIVE TECHNIC ON FOREARM STUMPS

While the patient is awake the muscl… groups to be utilized for this operation ar… visualized by having the patient contrac… the flexor and extensor muscles of the fore… arm Over these a flap is then outlined i… methylene blue (Fig 501) on the dorsa… aspect, and one on the volar aspect of th… stump The patient is then given a genera… anesthetic and the skin incised in the lin… of the outlined flap The base of the flap i… placed on the medial aspect of the stum… since the circulation is richer at this point

The incision is carried down to the mus… cle, forming a three sided flap of skin an… subcutaneous tissue The entire operation i… performed without a tourniquet in order t… avoid any interference with the circulatio… of the flap

After bleeding is controlled, the skin fla… is raised from its underlying bed by blun… dissection (Fig 502) The skin is undermined at the base of the flap in order t… insure a flexible motor The full thicknes… of the skin and subcutaneous tissue i… utilized The flap is then tested for an… possible restriction

The skin tube or loop is now prepared by

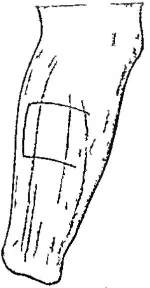


Fig 501 Skin is outlined in methylene blue on both volar and dorsal surfaces of stump

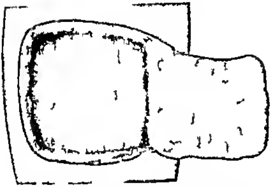


Fig 502 Skin flap is raised from underlying bed and includes full thickness of skin and subcutaneous tissue

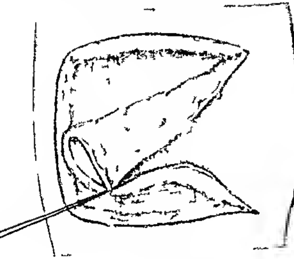


Fig 503 Tube is formed by reversing flap

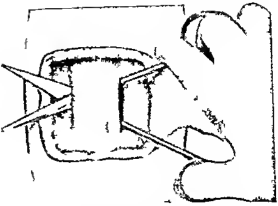


Fig 504 Two parallel incisions are made in muscle belly and an instrument passed through muscle to form a canal within it

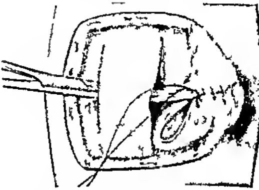


Fig 505 As tube is passed through canal traction suture must be kept in most superficial position to avoid distortion of tube

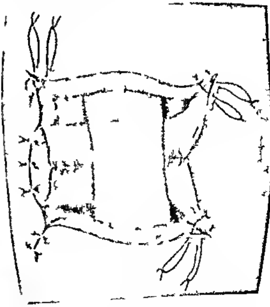


Fig 506 Edge of tube is sutured to adjacent skin, leaving a skin defect which must be closed

reversing the flap and securing the end of the tube so formed with a silk suture (Fig 503) This is used for traction as well as for fixation It is retained as a buried suture indefinitely or may be removed at the close of the operation

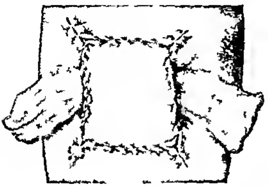


Fig 507 Skin defect covered with a Thiersch graft

Fig 508 (*Left*) Amputation just above wrist with volar and dorsal motors
Fig 509 (*Right*) Case shown in Fig 508, wearing prosthesis

The rest of the tube is approximated with subcuticular sutures of fine gut closely placed in order to insure perfect apposition In this manner wide scars are avoided, permitting friction of the peg, which is to be later inserted in the tube, without any resultant irritation or ulceration A probe is passed through the tube to demonstrate its patency

The tube is now retracted and the muscle prepared for canalization Two parallel incisions are made in the muscle belly and an instrument passed through the muscle to form a canal within it (Fig 504)

It is important to use muscle and not tendon for the canal since the latter has no contractility Movement of the canal depends on the alternate shortening and lengthening of the enclosing muscle as it contracts and relaxes

The skin tube is now passed through the canal in the muscle, the traction suture being kept in the most superficial position in order to avoid distortion of the tube (Fig 505) The edge of the tube is now sutured to the adjacent skin (Fig 506) This leaves a skin defect which must be closed In young children, in the upper arm in adults, and in those cases where there is a redundancy of skin in the amputation stump of the forearm it is possible to close the defect by direct approximation of the skin edges More frequently this cannot be accomplished without danger of skin necrosis In this event the wound defect is covered with a Thiersch graft (Fig 507) Zeroform gauze wicks are now inserted in the canals The first dressing is done in about ten days the pegs are inserted in about three weeks, and the stump is ready for prosthesis in about six weeks

Points of Importance The operative technic is quite simple There are only a few points that need emphasis to avoid failure It is important to select the proper muscle or muscle group for canalization It is impossible to tell beforehand just which muscles remain after the amputation We

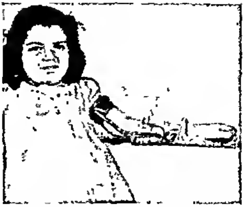
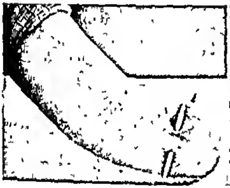


FIG. 510. (*Left*) Congenital amputation with volar motor in a four-year-old girl.
FIG. 511. (*Right*) Case shown in Fig. 510, wearing prosthesis.



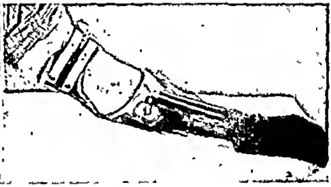
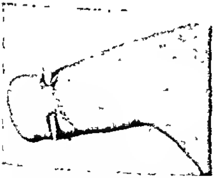


FIG. 512. (*Left*) Short forearm stump with double motors. (Courtesy, Kessler. Henry H.: Surg., Gynec., and Obstet.. 68:554-563.)
FIG. 513. (*Right*) Case shown in Fig. 512, wearing prosthesis. (Courtesy, Kessler, Henry H.: Surg., Gynec., and Obstet., 68:554-563.)



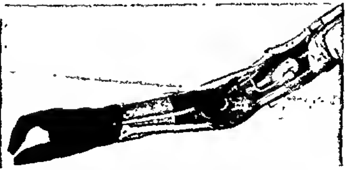


FIG. 514. (*Left*) Upper-arm amputation with biceps and triceps motors. (Courtesy, Kessler, Henry H.: Surg., Gynec., and Obstet., 68:554-563.)
FIG. 515. (*Right*) Case shown in Fig. 514, wearing prosthesis. (Courtesy, Kessler, Henry H.: Surg., Gynec., and Obstet., 68:554-563.)

depend, therefore, on the clinical test of visualizing the contraction of the muscles to be selected in response to the psycho-physiologic act of opening and closing the hand at the time of operation The patient must, therefore, be awake and the muscles outlined with a skin dye just before the operation is undertaken

The second important step neglect of which has been responsible for many failures in the past, is to canalize the muscle and not the tendon The latter has no con

Fig 516 Forearm and upper arm amputation with cineplastic prosthesis Re employed in hair felt factory repairing needle board (Courtesy, Kessler, Henry H Surg, Gynec, and Obstet, 68 554 563)

Fig 517 High upper arm amputation with cineplastic prosthesis Plays violin as avocation (Courtesy, Kessler, Henry H Surg, Gynec, and Obstet, 68 554 563)

tractility The activation of the artificial hand mechanism depends on the movement of the peg which passes through the tube The movement varies from ¼ to ½ inch, and is due to the alternate shortening and lengthening when the muscle contracts or relaxes

THE PROSTHESIS

It is not difficult to manufacture the kineplastic arm It is important that the weight of the apparatus be kept to a minimum Furthermore, the mechanism should be as simple as possible The more complicated the prosthesis, the less useful the arm Theoretical advantages should be sacrificed for practical utility For example, there is no need for incorporating a rotation mechanism at the wrist in forearm cases since pronation and supination of the stump

are still retained However, in upper arm amputation this rotation mechanism is of distinct value

The arm can be designed for heavy as well as light duty, depending on the indication of the specific case In the forearm amputation, no straps or apparatus are required above the elbow In the upper arm amputation a strap to the opposite shoulder is necessary to secure flexion of the elbow

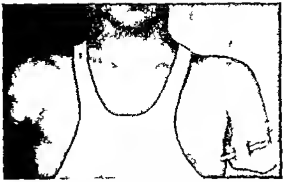


FIG 518 High double arm amputation following railroad accident Practically no stump remaining in right arm Biceps and triceps muscles canalized in left arm and fixation canal prepared in right shoulder stump (Courtesy Kessler Henry H Surg Gynec and Obstet 68 554 563)

RESULTS

The results of this kineplastic amputation in a personal series of 96 cases are distinctly encouraging Of this group 61 may be classified as highly successful (Figs 508

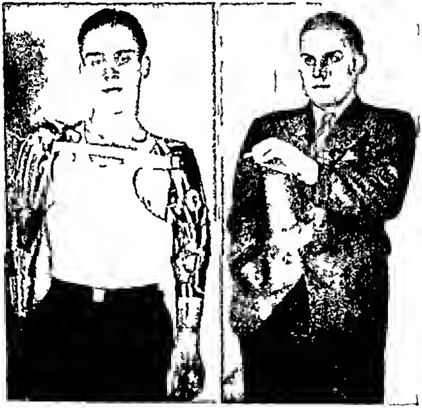


FIG 519 (*Left*) Front view with prosthesis showing peg through biceps canal Hand mechanism on left arm activated by biceps and triceps motors On right arm, elbow and hand mechanism is activated by cross straps on shoulders (Courtesy Kessler, Henry H Surg Gynec and Obstet 68 554-563)

FIG 520 (*Right*) Showing patient fully dressed (Courtesy Kessler, Henry H Surg, Gynec, and Obstet, 68 554 563)

520) These individuals are consistently using the prosthesis at work and in the routine pursuits of life over a period of from two to eight years Of the remaining 35, 20 enjoy partial utility of their prosthesis Unusual work requirements may render it impractical to wear the arm at work as in the case of one worker in a chemical plant who must immerse both arms in a solution as part of his work operation

Of the 15 that can be classified as failures, five have been due to surgical complications Infection of the skin canal, necrosis due to previous x ray dermatitis, improper placement of canals, too short a stump for utilization or leverage of muscle motors, and improper fit of the prosthesis account for these failures The remainder found it difficult to adjust themselves because of personality factors

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